Volume 14 OCTOBER 1930 Number 10

BULLETIN
of the
American Association *of* Petroleum Geologists

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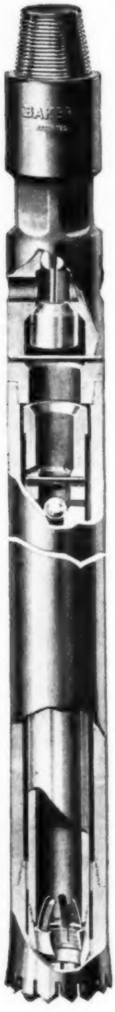

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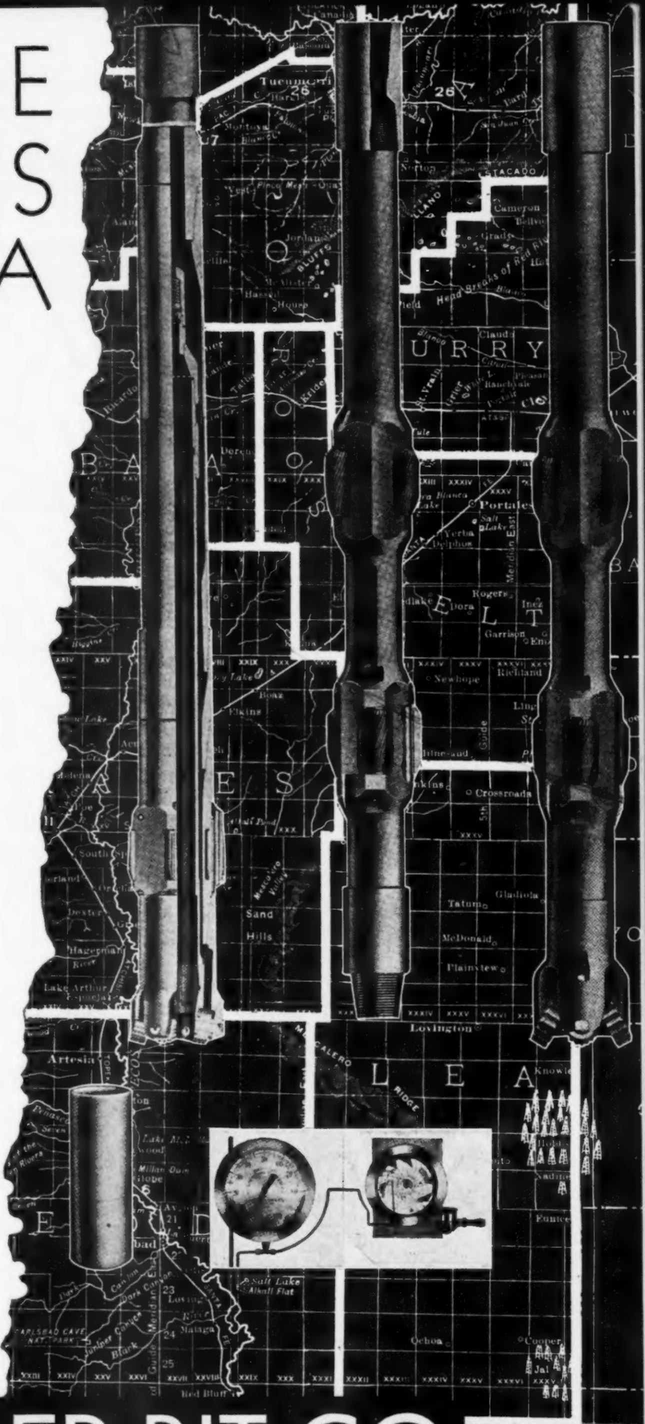

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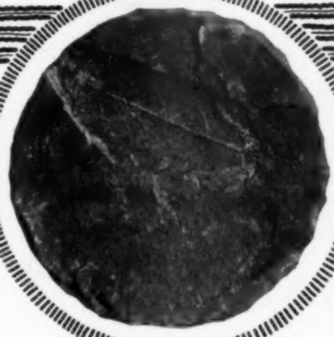

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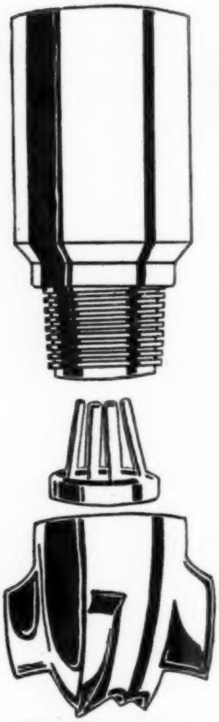

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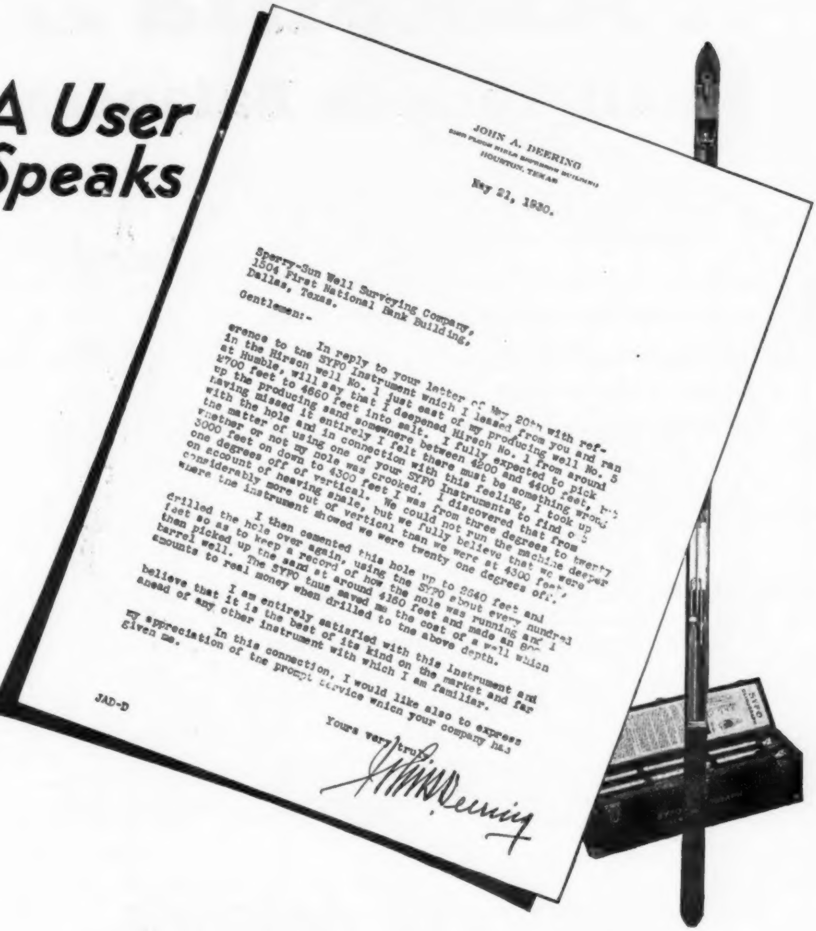

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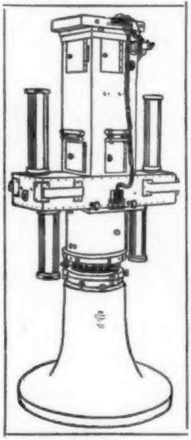

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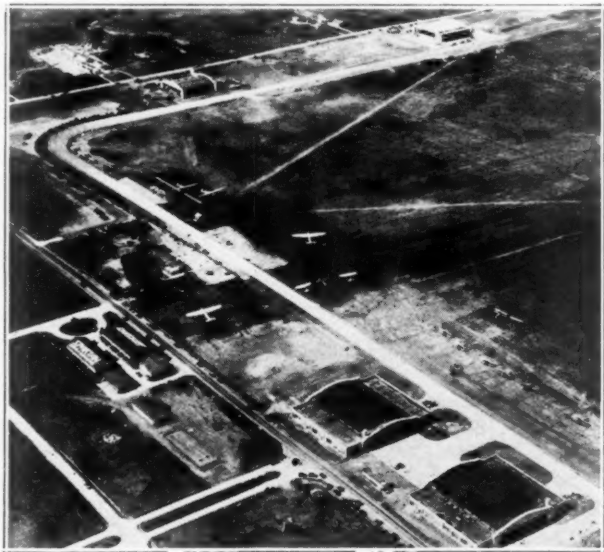

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OCTOBER 1930

REGIONAL EXTENT OF MARMATON AND CHEROKEE MID-CONTINENT PENNSYLVANIAN FORMATIONS[1]

ROBERT ROTH[2]
Bartlesville, Oklahoma

ABSTRACT

The writer has connected outcrops of the Cherokee and Marmaton on a faunal basis, and has projected these Pennsylvanian formational units by means of well samples throughout a very wide area, demonstrating the correlation of beds in Wyoming and Colorado with similar beds in Kansas and Oklahoma.

Some of the formations in Wyoming and western Colorado seem from their outcrops to belong to a province different from that of their equivalents which crop out in Kansas and Oklahoma; however, by means of well samples, the equivalence of these beds may be demonstrated and a mixing of the faunal suites shown, thus eliminating the possibility of different provinces.

The writer discusses the influences and regional conditions surrounding the deposition of the Marmaton and Cherokee.

The McCoy formation is here introduced. A brief faunal paper on the McCoy formation will appear in the *Journal of Paleontology*,[3] where all the new fossils mentioned in this paper will be described.

INTRODUCTION

In working on the outcrop of the Pennsylvanian beds in Oklahoma, Kansas, and Nebraska, the writer was much impressed with the continuity of beds, some of which are not more than a foot thick, which may be followed as separate units across Kansas into Nebraska and into Iowa, and in some places as far south as Oklahoma. Some of these beds, for

[1]Read before the Society of Economic Paleontologists and Mineralogists at the New Orleans meeting, March 21, 1930. Manuscript received by the editor, March 12, 1930.

[2]Indian Territory Illuminating Oil Company.

[3]December, 1930.

example, the Fort Scott limestone, may be traced from Oklahoma through Kansas, Missouri, and into Illinois, and beneath the surface for hundreds of miles toward the west.

The divisions of the Oread, Deer Creek, and Americus may likewise be traced through large areas. One example is a faunal zone at the base of the Heebner shale. This faunal zone is about ½ inch thick and may be followed from central Kansas northward to Platte River in Nebraska. The Heebner shale separates the Plattsmouth limestone from the Leavenworth limestone, upper and middle members of the Oread, respectively.

Inasmuch as these beds are continuous on the surface, the writer thought that some of the beds might be traced from well to well in a very large area, with the possibility of finding them again in the upturned edges of the Pennsylvanian, which occur on the east flank of the distant Rocky Mountains. Correlations of this nature have been made with the Dakota and other Cretaceous beds.

In order to do this work, careful detail sections have been of prime importance. They were taken along Platte River of Nebraska, along Kansas River valley, and Cottonwood River valley in northern Kansas; across Kansas from Sedgwick County east to Bourbon County; across northern Oklahoma from Vinita west to Perry; across central Oklahoma from the Ouachita Mountains to the town of Norman; and in a few places in the Ardmore basin of southern Oklahoma.

After preparing these sections, regional correlations were undertaken by means of well samples and immediately certain difficulties were encountered. It was noticed that the Pennsylvanian contains several unconformities, one of which was of great extent. This was not previously realized. The most pronounced unconformity occurred during the last great uplift of the Arbuckle and the Wichita mountains near the end of Lansing time and previous to most of the Douglas deposition. When this unconformity had been conclusively established, it was found that the beds above the Lansing and the Kansas City groups were so lenticular that they could not be correlated as extensively as the beds below. The orogenic movement of the Arbuckle and the Wichita mountains thus limited the work to beds of Marmaton and Cherokee ages, because they were not immediately influenced by any very pronounced uplifts. With the work of correlation concentrated upon these two time intervals further work was necessitated on the outcrop, which has yielded fossils of great value; in fact, the work could not have been completed without them.

During the summer of 1929 the writer was enabled to make detailed sections and an extensive collection of fossils from the Minnelusa of the Black Hills, from the Hartville formation along the Hartville uplift of eastern Wyoming, and from the McCoy formation of western Colorado. These beds were known to be of Pennsylvanian age, although their exact position in the Pennsylvanian, as far as the writer is aware, has until now not appeared in print. These sections alone, however, still did not yield sufficient detail concerning the ranges of certain fossils used. Subsequent to this period of collection from outcrops, fossils from many wells have been studied and identified. Aside from many large fossils which were very indicative, the genus *Fusulinella*[1] has been of most help, and because most of the species of this genus have not been published, the writer, in collaboration with J. W. Skinner, has prepared them for publication in the near future. Most of the new species occur in the McCoy formation in Colorado. They will be described in detail in a forthcoming paper.

There are several reasons for selecting the Marmaton and Cherokee for distant correlation. So far as the writer knows, the genus *Triticites* has not been found below the Kansas City; neither has the genus *Fusulinella* een found above the Marmaton. Inasmuch as *Triticites* is very common throughout the remainder of the Pennsylvanian, any regional correlations on the upper Pennsylvanian beds would be difficult where exact contacts are required. In the Marmaton several species of *Fusulinella* are plentiful and their vertical range is much restricted. For example, *Fusulinella girtyi* occurs only in a few feet of the basal Fort Scott limestone, although it is so plentiful that it is found in almost all well samples from this horizon. This clearly marks the base of the Marmaton. The Cherokee also has many species of the genus *Fusulinella*, which are characteristic. So far none of the Cherokee forms has been found in the Marmaton.

Since the lower Cherokee includes fossils which have been found in what has been called Pottsville elsewhere, probably not all of the Cherokee is Allegheny, but part may be Pottsville. At present the only method of separating the Allegheny from the Pottsville is by fossil plants, according to David White.

[1]Since the writing of this paper a communication has been received from Carl O. Dunbar of Yale University stating that he has had occasion to examine collections from the "Bergkalkschichten" of Mjatschkowa, U. S. S. R. It is from here that Fischer-de-Waldheim first described *Fusulina*. Dr. Dunbar states that the *Fusulina* described is in reality a *Fusulinella*. This means that all Fusulinellas here named should be called *Fusulina*, that *Fusulinella* as a generic name does not exist, and that all forms previously called *Fusulina* are without a generic name except those which have fusulinellid characteristics. Dr. Dunbar will publish this in the November number of the *American Journal of Science*.

ACKNOWLEDGMENT

The writer wishes to acknowledge the careful and conscientious work done by J. W. Skinner in sectioning and examining the material which the writer has collected from the outcrop.

EXPLANATION OF MAP

The best of several cross sections made in extending the correlation of the Marmaton and the Cherokee is outlined on the map of the Mid-Continent and eastern Rocky Mountain region (Fig. 1). On this map the sections are numbered and two other sections are also used because of their bearing on regional sedimentation. Most of the numbered sections consist of well logs, but on the extremities the sections are of the outcrop material. They are briefly described in numerical order.

SECTION 1

Section 1 is a composite of beds of Marmaton and Cherokee age, near Stonewall, Oklahoma. The fauna indicate that the top of the Marmaton should be placed between the Homer limestone and the Sasakwa limestone, members of the Holdenville formation. This evidence is based upon the upper limits of *Chonetes mesolobus* and *Fusulinella haworthi*, and *F. meeki* var. *robusta*. The Sasakwa limestone, therefore, is in the lower part of the Kansas City group. Below the Holdenville is the Wewoka, which contains a *Fusulinella* bed in the upper part. The *Fusulinellae* found in this bed are *F. inconspicua*. One of the basal sandstones of the Wewoka marks the base of the Marmaton. The Wetumka, which is next below, contains *Fusulinella meeki*, a characteristic form of the Cherokee. Farther down, in the Boggy formation, there is a *Fusulinella* bed near the top which contains *F. meeki* and a new species, *F. hartvillensis*, which is found in a limestone immediately overlying the Bluejacket sandstone or the Bartlesville sand. This new species is similar to that found in the Hartville formation of Wyoming, except that it is considerably larger. In the Hartshorne or Grady coal, plant remains have been found in "bone" partings near the top which, according to David White, are middle Allegheny. The Atoka formation, below the Hartshorne sandstone, is about 800 feet thick near Stonewall, and farther southeast it attains a thickness of 4,000 feet. The lower part of the Atoka is Pottsville. However, it is doubtful if very much of the Atoka at Stonewall is older than Allegheny. Several species of *Fusulinella* have been found in the Atoka approximately 500 feet below the top, where occur *Fusulinella meeki*, *F. meeki* var. *tregoensis*, and a new species.

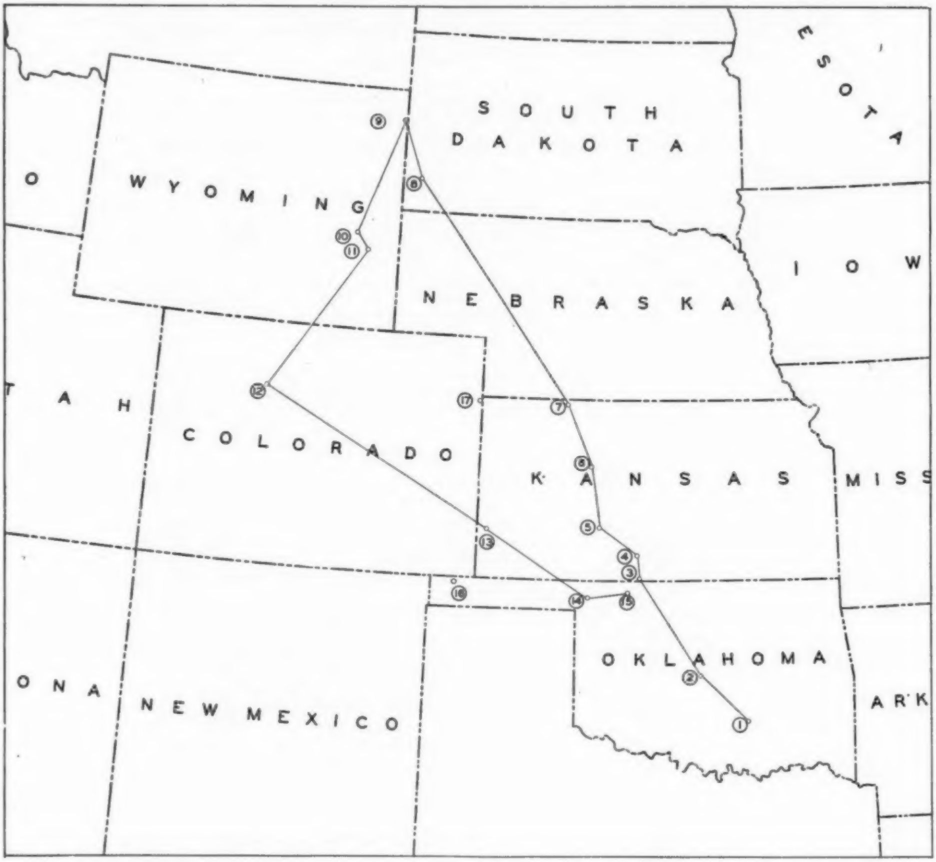

FIG. 1.—Map of Mid-Continent and eastern Rocky Mountain region showing locations of sections made in extending the correlation of the Marmaton and the Cherokee.

The Atoka at Stonewall rests upon the Wapanucka limestone, which is Pennsylvanian in age, but is pre-Pottsville. The enormous thickness of these clastic sediments above the Wapanucka limestone is noteworthy and is mentioned later under "Regional Consideration."

Beyond Stonewall, the cross section plunges beneath the surface, but comes up in the Black Hills of South Dakota.

COMPOSITE OF OUTCROP SECTION NEAR STONEWALL, T. 2 N., R. 7 E., PONTOTOC COUNTY, OKLAHOMA

Elevation, 750 feet. Figures show total thickness in feet, at bottom of beds described.

BEDS OF MARMATON AGE

0- 100 HOLDENVILLE. Gray shale

104 Limestone (HOMER LIMESTONE). *Chaetetes milleporaceus, Fusulinella hayworthi, F. meeki* var. *robusta*

144 Gray shales with some sandstones

544 WEWOKA. Sands and conglomerates at top and bottom. Conglomerates cherty with many sandstones throughout formation, one principally 90 feet above base. In upper part, a bed of *Fusulinella inconspicua*. Some conglomerates are arkosic

794 WETUMKA. A few thin sandstones near top and bottom. The remainder is dark gray shale. In upper 20 feet *Fusulinella meeki* has been found, indicating section from here down is of Cherokee age and older

BEDS OF CHEROKEE AGE AND OLDER

844 CALVIN SANDSTONE. Coarse-grained brown and grayish brown sandstone with a few layers of dark shale

969 SENORA. Dark gray shales with some brown and yellowish brown sandstones with somewhat massive sandstone 35 feet thick at base. Calcareous and fossiliferous in places

1,049 STUART SHALE. Dark shales, ranging through shades of green, blue, and black; fossiliferous. *Chonetes mesolobus*, et cetera

1,149 THURMAN SANDSTONE. Sands and conglomerates. Conglomerates cherty and contain Chimneyhill fossils, et cetera. Sandstones chiefly yellowish brown to brown and some shales are interbedded

2,249 BOGGY SHALE. Sandstones, shales, and a few limestones; principally shales. Fifteen feet below top of formation is *Campophyllum torquium*-limestone bed. Upper part of Boggy is sandy. Prominent sand beds 300 feet and about 500 feet above base. Several beds of *Fusulinella* near top of formation and probably close to *Campophyllum torquium* beds. *Fusulinella meeki* and *F.* sp., very similar to *F. Hartvillensis*, but about 75 per cent larger; also found in limestone immediately above Bluejacket sandstone in Sec. 7, T. 2 N., R. 18 E. (Oklahoma)

3,549 SAVANNA SANDSTONE. Alternating shales and sandstone with a few impure limestones and conglomerates. Jolly limestone member near base is very fossiliferous, containing huge *Bellerophon crassus* var. *wewokanus*. Similarity may be drawn here to Ingleside and *Bellerophon* limestones of western Colorado. Two very prominent sandstone beds in upper two-thirds of formation

5,049 McALESTER FORMATION. Upper 700 feet: almost entirely shale and contains McAlester coal, about 650 feet below top. Middle 500 feet: three or four beds of sandstone, separated by beds of shale of variable thickness. Lowest part: 600 feet of dark shales with some sandstone. Hartshorne or Grady coal occurs at base

6,249 ATOKA FORMATION. Alternating shales, sandstones, and conglomerates, especially in lower 400 feet. Shales are black and soft. About 500 feet below top is marly bed found in NE. ¼, Sec. 10, T. 5 N., R. 21 E, (Oklahoma), containing *Fusulinella meeki*, *F. meeki* var. *tregoensis*, and *F.* n. sp. Atoka rests unconformably on Wapanucka near Stonewall. Wapanucka is Morrow in age and is pre-Pottsville, because type Pottsville is younger than anything found in Morrow

SECTION 2

Section 2 is shown in the log of a well at Oklahoma City, the Indian Territory Illuminating Oil Company's Trosper No. 1. In this well the base of the Kansas City was encountered at 5,430 feet, and the base of the Marmaton at 5,995 feet. This section consists almost wholly of dark gray shales with a limestone at the base called the "Oswego" by drillers. The "Oswego" contains *Fusulinella girtyi*, which is known to occur only in the basal part of the Fort Scott limestone. Many fragments of large fossils were found in the Marmaton. The Cherokee commences at 5;995 feet and consists almost wholly of black shale with some sandstone in the lower part; the shales contain *Fusulinella meeki*(*?*), and *Fusulinella* sp. unidentifiable. Below the Cherokee at this place is the Ordovician or Chazyan.

SECTION IN INDIAN TERRITORY ILLUMINATING OIL COMPANY'S TROSPER NO. 1, CENTER, NE. ¼, SW. ¼, SEC. 13, T. 11 N., R. 3 W., OKLAHOMA COUNTY, OKLAHOMA

Elevation, 1,222 feet. Figures show depth in feet, at bottom of beds described.

BEDS OF MARMATON AGE

5,430-5,485	Dark gray shale. *Plagioglypta annulistriata*
5,490	Marl
5,500	Dark gray shale
5,505	Very dark gray shale
5,515	Oölitic limestone and sandstone
5,525	Very dark gray shale
5,530	Sandstone
5,540	Very dark gray shale
5,545	Oölitic limestone
5,560	Very dark gray shale. *Triticites* sp. (cave)
5,565	Limestone
5,600	Very dark gray shale. *Ambocoelia planiconvexa*, *Gastrioceras venatum ?*, *Orestes nodosus*, *Healdia* sp.
5,650	Very dark gray shale
5,680	Very dark gray shale. *Orthoceras tuba ?*
5,685	Sandy limestone
5,750	Very dark gray shale, brownish nodules at top
5,800	Very dark gray shale, gritty in places
5,848	Very dark gray shale
5,850	Limestone shell
5,900	Very dark gray shale
5,905	Dark brown grits and marl
5,910	Limestone shells

5,918	Dark brown and black shale. *Spirillina* sp.
5,930	Dark dense brown limestone
5,935	Black shale
5,945	Gray dense limestone. *Fusulinella girtyi*
5,948	Black shale
5,955	Gray dense limestone
5,958	Black shale
5,995	Brown granular, very porous limestone

BEDS OF CHEROKEE AGE

6,005	Black shale. *Roemerella patula*
6,018	Dark limestone. *Fusulinella meeki ?*
6,035	Black shale
6,040	Black shale and marl. *Fusulinella* sp.
6,048	Dark brown dense limestone
6,052	Angular sandstone, very micaceous, and carbonaceous (oil). *Marginifera* sp.
6,060	Dark brown dense limestone
6,070	Angular sandstone
6,075	Dark gray shale
6,080	Angular sandstone
6,092	Very slivery black micaceous shales

BEDS OF CHAZYAN ORDOVICIAN AGE

SECTION 3

Section 3 is in Kansas. It is shown in the log of the Blunk well of the Shaffer Oil and Refining Company. The Kansas City overlies the Marmaton, which commences at 4,515 feet and continues to 4,860 feet. The Marmaton here consists principally of black nodular shales and limestone. Sediments of a finer type predominate. The lower part contains some gray-green shales and chert. The Cherokee was encountered from 4,860 to 4,950 feet. It consists of gray shales, cherts, sandstones, and variegated shales. It rests upon the Mississippian, which probably is the very basal part of the Osage. The Mississippian limestone is very thin.

SECTION IN SHAFFER OIL AND REFINING COMPANY'S BLUNK NO. 1, SEC. 20, T. 34 S., R. 13 W., BARBER COUNTY, KANSAS

Elevation, 1,600 feet. Figures show depth in feet, at bottom of beds described.

BEDS OF MARMATON AGE

4,515-4,536	Black nodular shale
4,545	Limestone
4,565	Black shale and limestone shell
4,580	Limestone
4,595	Black shale and limestone
4,615	Limestone
4,620	Limestone and gray shale
4,635	Green shale and limestone
4,655	Gray-green shale and chert
4,685	Gray-green shale and limestone
4,695	Cherty limestone
4,705	Limestone

4,715	Gray shale and limestone
4,750	Calcareous grits and red beds
4,760	Dolomitic limestone
4,860	Micaceous gritty calcareous gray shale

BEDS OF CHEROKEE AGE

4,885	Gray shale and chert
4,890	Greenish shale and glauconite
4,915	Cherty limestone
4,930	Gray-green shale
4,935	Maroon shale
4,950	Gray-green shale

MISSISSIPPIAN, PROBABLY OSAGE

SECTION 4

Section 4 is part of the log of the Skelly Oil Company's Winters No. 1. In this well the Kansas City rests on Marmaton, which was encountered from 4,070 feet to 4,205 feet. The Marmaton consists chiefly of limestones with some chert and black shale. The limestone at the base contains *Fusulinella haworthi*, which occurs in the Fort Scott horizon. The Cherokee continues to 4,255 feet and is principally weathered chert and variegated shale. It rests on the Mississippian, which is probably very oldest Osage, although part of it may be Chester.

SECTION IN SHELL OIL COMPANY'S WINTERS NO. 1, CENTER, E. 1/2, SEC. 17, T. 31 S., R. 12 W., BARBER COUNTY, KANSAS

Elevation, 1,627 feet

BEDS OF MARMATON AGE

4,070-4,075	Black shale
4,105	Alternating buff dense to crystalline limestone
4,115	Oölitic black shale
4,120	Cherty limestone. Some of the chert is chalcedony
4,160	Gray dense limestone
4,175	Alternating dark gray shale and limestone
4,190	Marl and variegated shale
4,205	Limestone. *Fusulinella haworthi*

BEDS OF CHEROKEE AGE

4,220	Alternating dense limestone and greasy gray shale
4,225	Gray-brown shale
4,230	Weathered chert
4,240	Gray and brown shale
4,245	Chert
4,255	Brown shale

MISSISSIPPIAN, PROBABLY ALL OSAGE, BUT POSSIBLY CHESTER IN PART

SECTION 5

Section 5 is part of the log of the Amerada Petroleum Corporation-H. F. Wilcox Oil and Gas Company's Tansil No. 1. In this well the Kansas City overlies the Marmaton, which commences at 4,430 and continues

to 4,595 feet. The Marmaton is largely composed of limestone and variegated shales. The Cherokee continues to 4,905 feet, and contains several limestones, sandstones, variegated shales, and much chert near the base. The Cherokee in this well rests on the Ordovician (Galena).

SECTION IN AMERADA PETROLEUM CORPORATION-H. F. WILCOX OIL AND GAS COMPANY'S TANSIL NO. 1, SEC. 32, T. 25 S., R. 19 W. EDWARDS COUNTY, KANSAS

Elevation, 2,222 feet

BEDS OF MARMATON AGE

4,430-4,435	Black shale. *Glyptopleura* sp. ?
4,440	Gray shale
4,445	Limestone
4,455	Gray shale
4,470	Limestone
4,478	Dark gray shale
4,480	Limestone
4,490	Gray and brown shale, variegated
4,505	Limestone
4,510	Brown shale
4,518	Limestone
4,525	Variegated shale
4,532	Limestone
4,540	Red and green shale
4,550	Limestone
4,560	Variegated shale and limestone. Pelecypods and gastropods
4,570	Gray-green shale with some limestone
4,575	Limestone
4,595	Dense brown limestone

BEDS OF CHEROKEE AGE

4,600	Gray-green shale. *Chonetes mesolobus*
4,605	Gray shale
4,640	Alternating dark gray platy shale and fossiliferous limestones
4,645	Black nodular shale
4,655	Dark gray shale and fossiliferous limestone
4,668	Gray shale
4,675	Angular to frosted quartzitic sandstone and gray shale
4,680	Gray shale and glauconite
4,685	Brown shale, and some gray shale
4,690	Dense limestone
4,695	Sandstone
4,700	Gray shale
4,715	Reddish brown grits
4,725	Greenish gray shale, red grits, and red chert with some sandstone
4,728	Frosted sandstone, green limestone, and chert
4,738	Frosted sandstone
4,742	Limestone
4,745	Green shale with sandstone
4,750	White chert and tripoli
4,760	Black shale and chert
4,820	Weathered chert, containing some calcareous material and frosted sandstone
4,825	Gray shale
4,830	Calcareous chert
4,850	Weathered chert

4,870 Granular limestone and some chert
4,875 Gray shale
4,885 Weathered chert
4,890 Gray shale and frosted sandstone
4,895 Granular dolomitic limestone with weathered fossils. *Tentaculites* sp. ?, re-worked.
4,905 Quartzitic sandstone and some gray shale

ORDOVICIAN, GALENA

SECTION 6

Section 6 is part of the log of the Central Commercial Oil Company's King No. 1. The Kansas City rests on the Marmaton, which was encountered from 3,575 to 3,850 feet. *Fusulinella* sp., an unidentifiable form, is present. The section of Marmaton consists of limestones and shales. The Cherokee continues to 3,870 feet. *Fusulinella meeki* var. *tregoensis*, n. var. occurs in the lower brown shale. The Cherokee rests on the Mississippian (Osage) or possibly Ordovician (Galena). The Cherokee is composed of variegated shales with brown shales predominating in the lower part.

SECTION IN CENTRAL COMMERCIAL OIL COMPANY'S KING NO. 1, SEC. 20, T. 13 S., R. 21 W., TREGO COUNTY, KANSAS

Elevation, 2,249 feet

BEDS OF MARMATON AGE

3,575-3,580 Black shale
3,585 Limestone
3,590 Dark gray shale
3,598 Gray-green shale
3,600 Limestone
3,605 Gray-green shale
3,610 Limestone
3,615 Brown shale
3,620 Gray shale
3,625 Brown shale
3,635 Gray shale with limestone shells
3,640 Limestone with a little brown shale at top
3,645 Gray shale
3,655 Limestone
3,660 Brown shale
3,678 Limestone
3,680 Brown shale
3,688 Alternating brown shale and limestone
3,693 Limestone
3,695 Dark gray shale
3,705 Limestone
3,710 Chert
3,712 Brown shale
3,725 Limestone
3,738 Gray-green shale with limestone shells
3,743 Limestone
3,750 Gray-green shale
3,760 Limestone, cherty at top. *Fusulinella* sp. ?
3,765 Brown shale

3,775	Limestone, with gray shale at top
3,785	Alternating gray shale and limestone
3,795	Gray and brown shale
3,800	Limestone
3,805	Gray shale
3,850	Brownish dense lime partly dolomitized, with gray shales near the base

BEDS OF CHEROKEE AGE

3,855	Brown shale
3,860	Limestone
3,870	Brown shale
3,875	Limestone. *Fusulinella meeki* var. *tregoensis*
3,895	Brown shale
3,900	Variegated shale
3,910	Brown shale
3,918	Alternating limestone and brown shale
3,930	Brown shale
3,932	Reddish nodular limestone and gypsum
3,940	Brown shale
3,945	Limestone. *Prismopora sp.?*
3,955	Brown shale, with red chert fragments

MISSISSIPPIAN, OSAGE OR ORDOVICIAN, GALENA

SECTION 7

Section 7 is part of the log of the Marland Oil Company's Reager No. 1. In this well the Kansas City overlies the Marmaton. The exact top of the Marmaton can not be placed; however, at 3,625 feet several *Fusulinella* sp. are present, and in the limestone from 3,745 to 3,750 feet *Fusulinella haworthi* was encountered, which marks the Fort Scott horizon. The Cherokee continues to 3,850 feet. The section is composed of brown shale, limestones, and arkosic sandstones at the base. The Cherokee rests on the Cambrian or Deadwood.

SECTION IN MARLAND OIL COMPANY'S REAGER NO. 1, SEC. 25, T. 2 S., R. 26 W., DECATUR COUNTY, KANSAS

Elevation, 2,591 feet

BEDS OF MARMATON AGE[1]

3,625-3,630	Limestone. *Fusulinella* sp. ?
3,645	Brown shale
3,650	Limestone. Bryozoans, pelecypods, brachiopods
3,655	Brown shale
3,685	Brown shale
3,690	Gray shale
3,705	Limestone. *Cytherella*
3,710	Brown shale
3,730	Limestone. Crinoids, gastropods
3,735	Gray-brown shale
3,740	Limestone
3,745	Gray-brown shale
3,750	Limestone. *Fusulinella haworthi*

[1]Due to a skip in samples from 3,565 to 3,625, the exact top of the Marmaton can not be placed.

BEDS OF CHEROKEE AGE[2]

3,758	Brown shale
3,762	Limestone
3,765	Brown shale
3,770	Brown shale with light shale
3,780	Brown shale with dark gray shale
3,785	Limestone
3,790	Brown shale
3,795	Glauconitic angular arkosic sandstone
3,800	Gray shale, quite fissile, contains fossil fragments
3,803	Brown shale
3,807	Limestone
3,810	Calcareous sandstone
3,820	Calcareous red and gray grits, with violet-colored shale
3,833	Limestone
3,837	Brown shale
3,842	Arkosic sands and brown shale
3,850	Angular arkosic sand

CAMBRIAN, DEADWOOD

[2]The sediment below 3,750 feet may also be Marmaton; however, due to the restricted range of *Fusulinella haworthi*, it is more than probable that it limits the base of the Marmaton in this well.

SECTION 8

Section 8 is at the outcrop at Loring Siding, South Dakota. In the Minnelusa section of the Black Hills there are two major divisions,—a lower part, the equivalent of the Amsden, and an upper part, the equivalent of the Tensleep. Concerning the age of the Tensleep, the writer believes that in different places different sandstones are known as the Tensleep. At least, in southeastern Wyoming, where the Tensleep separates the Setanka shale from the Casper formation, it clearly marks an unconformity. In the Black Hills the Tensleep seems to be within the same group as the Amsden, with an unconformity above. This seems to corroborate I. A. Keyte's description of the Kansas City-Marmaton fauna immediately above the Tensleep near its type locality, Sheep Mountain, Wyoming. The upper part of the Minnelusa is probably Kansas City in age. The section at Loring Siding was measured below that part of the Minnelusa thought to represent the Tensleep. The section is composed of sandstone, limestone, and some chert. It contains a *Fusulinella*, which closely resembles *F. euthusepta*, which definitely places most of the Amsden in the Cherokee. Associated with this form are *Spirifer rockymontanus* and other forms. The Cherokee here rests on the Mississippian Pahasapa limestone, which, according to G. H. Girty, is probably lower Osage in age.

SECTION IN OUTCROP AT LORING SIDING, CENTER, SEC. 4, T. 6 S., R. 4 E., CUSTER COUNTY, SOUTH DAKOTA

Elevation, 4,700 feet

BEDS OF KANSAS CITY AGE (TENSLEEP). PROBABLY IN PART MARMATON HERE

BEDS OF CHEROKEE AGE

0- 10	Limestone, purplish and sandy
70	Beds mostly covered, shales above, sandstone below
80	Buff calcareous sandstone
83	Massive reddish sandstone, with flint nodules and vugs
133	Light yellowish buff and pinkish sandstone, mostly thin-bedded, with a few ½-inch beds of light-colored chert
163	Fine-grained pinkish limestone. Contains a few beds of clay and several beds of black shale and a 3-inch layer of black chert at base
188	Quartzite and covered slope
238	Massive brownish and buff sandstone and calcareous marl
250	Buff sandstone, sandy, with considerable shale
275	Buff sandstone
305	Drab limestone with pink flint streaks. *Fusulinella euthusepta ?* (A form with straight septa, definitely of Cherokee age). *Spirifer rockymontanus*, *Composita subtilita*, *Euphemus nodicarinatus*, and other forms
320	Massive pink calcareous sandstone with calcite veins
332	Purplish drab calcareous marl
357	Massive pink calcareous sandstone with calcite veins
375	Massive drab limestone
383	Rubbly pink sandy limestone
408	Red shaly quartzitic sandstone

MISSISSIPPIAN, PAHASAPA LIMESTONE

SECTION 9

Section 9 was measured west of the LaPlant Ranch in Wyoming, where the upper part of the Minnelusa is Kansas City or Marmaton in age and represents the Tensleep horizon. The Marmaton is probably not very thick. Most of the section is Cherokee, consisting of limestones and sandstones, predominately of a reddish color, resting on the Pahasapa.

SECTION IN OUTCROP AT LA PLANT RANCH, SEC. 24, T. 52 N., R. 60 W., CROOK COUNTY, WYOMING

Elevation, 3,750 feet

BEDS OF KANSAS CITY AGE

BEDS OF MARMATON ? AGE

BEDS OF CHEROKEE AGE

0- 41	Red to gray thin-bedded limestones and sandstones
111	Red to gray thin-bedded limestones, marls, and some sandstones
177	Pink to gray thin beds of limestones and sandy shales
263	Pinkish gray to gray limestone and sandstone, some fossils
336	Pinkish gray to gray sandy limestones
356	Red quartzitic sandstone

MISSISSIPPIAN, PAHASAPA LIMESTONE

SECTION 10

Section 10 was measured on the outcrop approximately 30 miles northwest of Guernsey, Wyoming. Here the upper part of the Hartville is Kansas City in age. No fossil indications of Marmaton were found. What is probably Marmaton is about 90 feet thick and consists of limestone, chert, and marl. The Cherokee is very fossiliferous, and is about 147 feet thick down to the edge of the Platte River. It contains *Fusulinella hartvillensis*, *F. minutissima*, and *F.* n. sp. The lower Hartville is not exposed.

OUTCROP SECTION,[1] SEC. 8, T. 30 N., R. 69 W., PLATTE COUNTY, WYOMING
Elevation, 4,840 feet

BEDS OF KANSAS CITY AGE

0- 50	Limestone, thin-bedded, forming a slabby slope
70	Limestone, heavy-bedded to massive, pure, fine-textured, nearly white Fossils: *Linoproductus cora* var., and *Triticites*, 4 n. sp. Contains a *Triticites* oölite, identical with a *Triticites* oölite in the Drum limestone
120	Limestone, light gray, cliff-forming. No fossils observed
123	Reddish argillaceous limestone. *Triticites*, 3 n. sp., and crinoidal fragments
168	Limestone, light gray, cliff-forming, with reddish chert lenses in the base

BEDS OF MARMATON ? AGE

193	Limestone, light gray, massive, with geodes
243	Unstudied, interval including alternating heavy ledges of limestone and shaly slopes
248	Limestone, light gray in heavy, ledge-forming bed
258	Covered slope

BEDS OF CHEROKEE AGE

268	Limestone, light gray, with thin lenses of brownish chert. Heavy ledge-forming beds
276	Covered slope (may have limestone in it)
283	Limestone in 3 layers, basal layer, pure, heavy, the second light gray and marked by geodes, the upper forming gray slabs filled with *Fusulinella hartvillensis*, *F. minutissima*, F. sp.
293	Covered slope
297	Limestone in 2 layers, lower a heavy bed of pure, light gray limestone, and the upper a darker gray and filled with *Fusulinella hartvillensis*, *F. minutissima*, *F.* sp.
313	Covered slope
321	Limestone, light gray, compact, pure, with thin lenses of brownish chert. *Marginifera muricata* and several kinds of small gastropods
329	Sandstone, soft, friable, light gray, cross-bedded
337	Limestone, brittle, platy. *Chonetes mesolobus*, *Marginifera splendens*, *Ambocoelia planoconvexa*
340	Covered slope
342	Quartzite, pink, hard, fine-grained, brittle
344.5	Limestone in a hard ledge, passing into limestone breccia at the top
351.5	Limestone, light gray, compact, and brittle

[1]Section at the north end of Platte Canyon about 5 miles south of Orin Junction, Wyoming. Beds 1 - 6 measured by G. E. Condra and dictated from memory at camp in Guernsey, September 9, 1929. Beds 8 - 28 were measured in detail by C. O. Dunbar and A. L. Lugn, working from the base up until darkness halted the work. The entire section is described from the top down.

354 Limestone, platy and laminated, of lavender color. *Chonetes mesolobus, Cleiothyridina orbicularis*
357 Limestone, earthy-textured, nearly pure, light gray, with small chert nodules. A heavy, ledge-forming bed. *Spirifer rockymontanus, Productus coloradoensis, Linoproductus cora* var.
362 Sandstone, forming a compact, massive, cross-bedded layer
365 Silty limestone with lavender shale partings
372 Limestone, light gray, silty, heavy-bedded
408 Slope of red sandy shale to the river level

PLATTE RIVER

SECTION 11

Section 11 is a section of the Cherokee part of the Hartville, in a high hill which marks the south side of Guernsey dam at Guernsey, Wyoming. The Cherokee here is approximately 482 feet thick. The Hartville here rests upon the Mississippian or Guernsey formation which is the equivalent of the Pahasapa.

SECTION[1] NEAR GUERNSEY, NW. COR., SEC. 27, T. 27 N., R. 66 W., PLATTE COUNTY, WYOMING

Elevation, 4,750 feet

HARTVILLE FORMATION. CHEROKEE AGE

75-100 Limestone, seen in the bluffs along the rim of the canyon a mile or more upstream from the measured section
0- 1 Limestone, weathering to brittle platy slabs
4 Limestone, harsh, brittle, gray, with fragmentary fossils
10 Covered slope
15.5 Limestone, massive, earthy, gray. Fossils fairly plentiful. *Chonetes verneiuilianus, Fusulinella* sp., very poor
28.5 Sandy limestone in poorly defined beds, with yellowish chert
33.5 Sandstone, yellowish gray, forming a massive ledge, upper 1½ feet slabby, the remainder in one layer
65.5 Steep slope on poorly exposed beds of slabby light gray sandstone interbedded with thin layers of sandy limestone
74.5 Limestone, gray, fossiliferous; massive above and slabby below, containing yellowish chert
83.5 Sandy shale and slabby limestone
95.5 Dark gray limestone, sandy in middle and upper part. Lenses of red chert at base and top
124.5 Covered slope, probably largely formed of sandstone
128.5 Hard, light gray limy sandstone
133.5 Silty, light gray limestone with reddish chert nodules
138.5 Unexposed slope
144.5 Light gray friable sandstone
164.5 Unexposed slope with evidence of lavender mudstone above middle
190.5 Poorly exposed slope capped by friable white sandstone, underlain by red shale. Below middle of this interval occur small slabs of brittle dark gray limestone filled with small *Fusulinellae. Fusulinella rockymontana, F. distenta ?, F.* sp. cf. *F. meeki*
202.5 Red shale slope capped by ledge of light gray friable sandstone, the base of which is not exposed

[1]Section measured in a high hill at south side of the Guernsey dam at Guernsey, Wyoming. The lower part, up to bed 10, was measured by C. O. Dunbar and A. L. Lugn; the upper part was measured and dictated in the field by G. E. Condra. The section is described in natural order, from the top down.

205.5 Gray limestone in single ledge
215.5 Unexposed slope
216.5 Light gray indurated mudstone filled with fossils including *Chonetes mesolobus*, *Marginifera muricata*, *Spirifer rockymontanus ?*
225.5 Red shale slope
230.5 Light gray, brittle, silty limestone in one ledge
232.5 Lavender and gray spotted mudstone
237.5 Red slope
238.5 Gray limestone ledge with *Fusulinella* sp. cf. *F. meeki*, *F. excentrica*, *F. coloradoensis ?*, *F. distenta*, *F. rockymontana*, *Prismopora*
250.5 Covered slope
253 Hard, brittle, pink quartzite
261 Red shale slope
267 Gray limestone with plentiful fossils
285.5 Gentle covered slope
287.5 Gray limestone ledge forming a bench. Base covered
310.5 Gentle slope on maroon shale
313 Light gray limestone in single ledge
315.5 Red shale
326.5 Slope with evidence of red shale capped by ledge of gray limestone
327.5 Hard ledge of red or purple limestone
337.5 Poorly exposed interval in the slope with evidence of lavender-stained limestone breccia near base
340 Light gray limestone
343.5 Unexposed slope
348 Light gray limestone in heavy ledge
356 Maroon shale slope
361 Compact light gray limestone in heavy ledge
373 Lavender shale filled with rubbly lumps of limestone. Some free fossils
377 Gray crinoidal limestone
382 Granular, limy sandstone with many worn fragments of shell. Gray and pink mottled. Some *Spirifers* of the type of *S. rockymontanus*
482 Brick-red to maroon sandstone and sandy shale. Thickness not uniform because beds rest on strong erosional unconformity at top of the Guernsey limestone

SECTION 12

Section 12 was measured at McCoy, Colorado. The Pennsylvanian sediments at McCoy are here given the name McCoy formation[1] for the following reasons. The beds form the lower part of the so-called "Undifferentiated Carboniferous" on the Colorado state geological map. The fauna[2] found in the section is a unit and can not be divided into zones. Correlation with the Mid-Continent can be made precisely. The McCoy formation is unique. It is very fossiliferous, fossils occurring in thin beds of limestone and black shale, which are separated from each other by beds of red shales and massive arkosic conglomerates 50 feet or more in thickness. The thickness of these conglomerates above the measured section is unknown. There were three very fossiliferous zones from which

[1]According to the Committee on Geologic Names, of the U. S. Geological Survey, the name McCoy has not previously been used as a stratigraphic term.

[2]The micro-fauna of the McCoy formation will be published in the next few months.

collections were extensively made. From the general aspect of all the fossils, the section seems to be in the lower Cherokee. The McCoy formation rests on undifferentiated Cambrian or Ordovician and granite.

When the outcrop sections of the Rocky Mountain region were first studied, it was believed that the region represented a province somewhat different from the Mid-Continent. The large fossils were the same, but the micro-fauna was different. However, the sections encountered by the Sinclair Oil and Gas Company in western Oklahoma, and in the Ramsey wells in Cimarron County, Oklahoma, showed commingling of typical Mid-Continent and Rocky Mountain forms. The difference can only be explained by a slight variation in environment.

OUTCROP SECTION OF PENNSYLVANIAN, BETWEEN SEC. 5 AND 6, T. 2 S., R. 83 W., EAGLE COUNTY, COLORADO

Elevation, 7,500 feet

PENNSYLVANIAN UNDIFFERENTIATED. Alternating coarse sands, massive conglomerates, very arkosic, and shales. Predominant color, red

BEDS OF CHEROKEE AGE (MCCOY FORMATION)

0- 12 Coarse sandstones and massive conglomerates
20 Variegated shale
60 Red and white sandstones, cross-bedded, with massive conglomerates, also cross-bedded
85 Variegated shale and sandstone
88 Coarse sandstones and limestone nodules, fossiliferous
90 Coarse conglomerate
97 Dark shales, limestone nodules, fossiliferous and sandy
137 Coarse sandy conglomerates and sandstones, variegated and cross-bedded
149 Variegated sandy shales
154 Platy arkosic sandstone
159 Variegated sandy shales
160 Alternating platy limestones and black shales. *Chonetes mesolobus, Prismopora* sp., crinoids (very plentiful), brachiopods, *Fusulinella excentrica* var. *magna, F. distenta, F. rockymontana, F. coloradoensis, F. excentrica*
171 Black shale
179 White arkosic conglomerate
199 Variegated sandstone
224 Sandy arkosic conglomerate, cross-bedded
232 Arkosic conglomerate, very coarse, and cross-bedded
272 Variegated shale, sandstone, and interbedded conglomerate layers
275 Massive to platy arkosic sandstone
281 Variegated shale
311 Very dark non-fossiliferous shale
317 Dark limestone. *Fusulinella excentrica, F. coloradoensis, F. rockymontana*
321 Dark fossiliferous marl. *Fusulinella coloradoensis, F. coloradoensis* var. *perforata, F. rockymontana* (very plentiful)
329 Arkosic conglomerate
335 Black micaceous shale
339 Arkosic conglomerate
355 Very dark shale, micaceous
361 Very coarse arkosic conglomerate

861 Series of red micaceous shales, coarse and fine arkosic sandstone, grading downward into very coarse conglomerates composed of pink granite. Many beds of black micaceous shales in upper part of this 500 feet. Zone of large fossils near 561 feet. These fossils have been identified by Carl O. Dunbar, as follows.

Chonetes mesolobus var. undescribed. This *Chonetes* is common. The lobation is almost or quite obsolete and the surface characters are obscured, but I believe the shell is related to the *Chonetes mesolobus* stock. This may be the shell identified by Girty as *Chonetes geinitzianus*. It is not that species
Derbya crassa
Orbiculoidea sp., large
Pustula nebrascensis, common. May include also *Pustula symmetrica*, but in crushed condition these species can not be safely separated
Meekella ?—One fragment, apparently a dorsal valve
Spirifer boonensis—this common *Spirifer* is certainly the one so identified by Girty, but I can not be sure whether the Colorado shell is the same as that originally described from Missouri
Spirifer rockymontanus ?—four rather uncertain specimens
Productus aff. *gallatinensis*—two fragmentary shells
Schizodus sp. aff. *S. wheeleri*—fragment
Leda bellistriata
Myalina swallovi. *Ambocoelia planoconvexa*
Composita subtilita
Pinna sp.—fragment

1,011 Series of thin-bedded pink quartzites, interbedded with maroon and red micaceous shales. This last 200 feet± is separated from foregoing section by seeming unconformity. Unconformity probably due to nature of sediments, which are deltaic

UNDIFFERENTIATED CAMBRO-ORDOVICIAN

Sediments are probably all Cambrian, down to granite

SECTION 13

Section 13 is part of the log of the Wood Oil Company's Ranson No. 1 in Kansas. The Kansas City was found on the Marmaton at 4,295 feet. The sediments contain many fusulinids down to 4,945 feet, including *Fusulinella girtyi* and *F. haworthi*. At 4,945 feet the Cherokee black shale was encountered. It rests on the Mississippian or Chester at 5,355 feet.

SECTION IN WOOD OIL COMPANY'S RANSON NO. 1, NW. 1/4, SEC. 5, T. 26 S., R. 41 W., HAMILTON COUNTY, KANSAS

Elevation, 3,460 feet

BEDS OF MARMATON AGE

4,295-4,305	Very dark gritty shale
4,315	Limestone and gray-brown shale
4,340	Oölitic limestone
4,365	Limestone. Many ostracods
4,385	Limestone, gray shale, and sandstone
4,400	Gray and green shale with chert and limestone. Some of this material seems to be faulted
4,420	Carbonaceous shale and limestone
4,450	Oölitic sandy limestone
4,460	Black micaceous sandy shale, very fissile
4,475	Limestone and gray shale
4,495	Black shale. *Roemerella patula*
4,505	Black shale and very coarse oölitic limestone
4,515	Limestone. *Fusulinella girtyi*

4,525 Black shale and chert
4,540 Black nodular shale with greasy green shale at base
4,565 Cherty limestone and dark gray shale. *Fusulinella girtyi*
4,595 Nodular black shale and limestone shells
4,605 Limestone
4,620 Dark gray shale
4,635 Black nodular shale
4,670 Black shale and limestone, containing glauconite
4,680 Black shale, slightly calcareous
4,690 Limestone and black shale
4,705 Black shale
4,725 Sandy limestone, glauconitic in places, and black shale
4,740 Dark gray shale
4,760 Cherty limestone and dark gray shale
4,770 Limestone
4,790 Gray shale and marl. *Bairdia* sp.
4,850 Alternating limestone and dark gray shale. *Fusulinella haworthi, F.* sp., also large bryozoans, fragments of which resemble *Prismopora*
4,905 Alternating limestones and dark gray shale, glauconitic in places
4,915 Limestone
4,918 Gray marl
4,945 Gray gritty limestone. *Prismopora*, brachiopods

Beds of Cherokee Age

4,955 Nodular black shale
4,995 Alternating limestone and black shale with cherty limestone
5,015 Dark gray shale
5,025 Drab shale and coal
5,055 Gray and black shale with limestone shells and pyrite. *Nuculopsis ventricosa ?*
5,070 Fissile gray shale
5,100 Coal and black nodules in gray shale. Much pyrite. Material seems to be much squeezed
5,115 Glauconitic calcareous sandstone
5,120 Gray shale
5,160 Very fissile black shale. Conodonts
5,165 Glauconitic frosted sandstone
5,250 Black shale with some limestone concretions
5,260 Limestone and black shale, coarsely crystalline and glauconitic
5,270 Black shale
5,275 Sandstone
5,290 Black shale and limestone shells. Bryozoans
5,300 Glauconitic frosted sandstone, quartzitic
5,305 Green-gray shale
5,355 Angular and frosted sandstone, calcareous in places

Mississippian, Chester

SECTION 14

Section 14 is part of the Sinclair Oil and Gas Company's Howell No. 1. Beds of Kansas City age rest on the Marmaton at 6,170 feet. *Fusulinella haworthi* was found at 6,280 feet and the base of the Marmaton was at 6,465 feet. The Cherokee is extremely fossiliferous, especially in the lower part. The base of the Cherokee is at 6,943 feet, where it rests on the Mississippian, Chester.

SECTION IN SINCLAIR OIL AND GAS COMPANY'S HOWELL NO. 1, SW. 1/4, SEC. 14, T. 26 N., R. 24 W., HARPER COUNTY, OKLAHOMA

Elevation, 2,296 feet

BEDS OF MARMATON AGE

6,170-6,180	Dark gray shale
6,190	Dark gray shale, with black shale, containing iron concretions, fossiliferous
6,200	Black shale, gritty. *Nucula wewokana ?*
6,208	Dense brown to buff cherty limestone
6,225	Dense brown limestone, contains *Serpula* and *Euphemus carbonarius*, *Deltopecten* sp.
6,230	Brown shale
6,255	Brown limestone
6,260	Gray shale and gray to buff granular limestone
6,270	Buff granular limestone
6,280	Gray shale and gray to buff granular limestone
6,290	Brown sucrose limestone, chert, and some coal. *Fusulinella haworthi?*
6,310	Gray granular limestone. Core 10-16, 1 foot of gray granular limestone and dolomite at top. 1.5 feet fine black shale at bottom
6,350	Brown to buff limestone
6,355	Buff to tan limestone, very porous and contains gray shale
6,400	Tan limestone, not very porous
6,405	Cherty tan limestone
6,450	Tan limestone, not porous
6,465	Dark gray-brown limestone. *Chaetetes* sp.

BEDS OF CHEROKEE AGE

6,465-6,470	Chert and dark gray shale. *Fusulinella distenta ?*
6,490	Alternating black shale and marl
6,500	Dark brown limestone and black chert. *Fusulinella hartvillensis*
6,505	Black shale
6,510	Dark brown limestone
6,515	Black shale
6,520	Dark brown limestone
6,530	Black granular shale
6,545	Dark brown limestone. *Fusulinella hartvillensis ?*
6,550	Dark gray shale
6,555	Dark brown limestone
6,560	Black shale
6,570	Dark gray granular limestone. *Fusulinella meeki*, *F. hartvillensis*, *F. coloradoensis*, *F.* n. sp.
6,575	Black shale
6,580	Dark limestone
6,585	Black shale
6,590	Dark limestone
6,595	Black shale
6,615	Gray limestone, black shale, and coal
6,620	Black shale
6,635	Dark gray limestone. *Fusulinella rockymontana*, *F. minutissima*, *F.* sp.
6,640	Black shale
6,645	Dark limestone
6,650	Black shale
6,680	Black shale with limestone shells, very faintly variegated at base. *Fusulinella hartvillensis*, *F. meeki* var. *tregoensis*
6,685	Dark limestone
6,695	Platy fissile gray shale and green shale
6,705	Black shale

6,720 Gray oölitic limestone, very porous and dense in last 5 feet. Good showing of oil. *Fusulinella meeki*
6,725 Black shale
6,735 Dark limestone. *Fusulinella distenta*
6,740 Black shale and limestone shells
6,745 Cherty limestone
6,755 Black shale and black limestone. *Fusulinella minutissima*
6,760 Black shale
6,770 Black shale and black limestone. *Fusulinella minutissima, F. minutissima* aff., *F. hartvillensis, F. distenta, F. coloradoensis ?*
6,780 Black limestone and black chert. *Astartella concentrica, Worthenia tabulata*
6,785 Black shale
6,795 Brown and gray limestone. *Orestes nodosus, Gastrioceras venatum*, et cetera, *Fusulinella meeki, F.* sp., and *Chaetetes milliporaceus*
6,800 Very nodular black shale
6,805 Black limestone and black shale with gray limestone
6,810 Black shale
6,816 Black limestone
6,820 Fine angular quartzitic sandstone and gray shale
6,830 Black limestone and black shale. *Chonetes mesolobus, Orthoceras tuba?*
6,835 Dark marl
6,840 Dark fissile shale
6,845 Dense brown limestone
6,850 Black limestone. *Fusulinella* sp.
6,855 Dark gray shale
6,860 Glauconitic sandy grits
6,870 Dark shale, and green shale streaks
6,875 Grits and nodular gray shale with carbonaceous material
6,880 Black shale
6,885 Black dense oölitic limestone
6,895 Dark fissile shale. *Globivalvulina bulloides, Euphemus carbonarius, Marginifera* sp.
6,900 Tight glauconitic sandstone
6,915 Dark gray shale, brownish cast
6,920 Black oölitic limestone
6,925 Dark frosted sandstone, glauconitic
6,930 Angular to frosted sandstone and dark limestone
6,943 Tight angular sandstone, glauconitic, and very calcareous at base. Fish teeth

MISSISSIPPIAN, CHESTER

SECTION 15

Section 15 is part of the Sinclair Oil and Gas Company's Share No. 1. In this well the Kansas City rests on the Marmaton, which commenced at 5,425 feet and continued to 5,580 feet. It is very fossiliferous. The Cherokee contains *Fusulinella meeki, F. meeki* var. *tregoensis*, and other forms. The base of the Cherokee is at 5,835 feet, resting on the Chester.

SECTION IN SINCLAIR OIL AND GAS COMPANY'S SHARE NO. 1, SW. 1/4, SEC. 33, T. 27 N., R. 16 W., WOODS COUNTY, OKLAHOMA

Elevation, 1,777 feet

BEDS OF MARMATON AGE

5,425-5,440 Very dark shale
5,450 Black nodular shale and dark limestone

5,460 Dark gray gritty micaceous shale
5,465 Dark gray shale and limestone
5,475 Brown to buff limestone
5,485 Dark gray shale
5,490 Dark gray shale and limestone
5,505 Dark gray and black nodular shale
5,515 Dark gray shale and limestone
5,520 Brown limestone
5,530 Dark gray to black shale
5,535 Dark gray and brown limestone
5,560 Fissile, dark gray shale, light gray in part. *Ambocoelia planiconvexa, Trepospira depressa*
5,565 Fine granular, pale green dolomite
5,570 Dark gray shale
5,575 Greasy gray-green shale. *Gastrioceras venatum ?*
5,580 Dark gray shale

BEDS OF CHEROKEE AGE

5,590 Dark gray shale, and some dense buff limestone. *Astartella concentrica, Yoldia glabra ?, Fusulinella meeki, F. meeki* var. *tregoensis*
5,605 Fissile gray shale
5,615 Oölitic to dense buff limestone. *Fusulinella* sp., *Staffella* sp. This form somewhat resembles *Orobias*
5,620 Dark gray shale
5,625 Fissile gray shale
5,630 Limestone
5,645 Gray to black gritty shale
5,650 Gray fissile shale and some limestone. *Chonetes mesolobus, Fusulinella* sp., *Coloceras liratum*
5,660 Gray shale and limestone
5,670 Oölitic limestone and black shale. *Phanerotrema grayvillense*
5,680 Limestone and dark gray shale, with dark gray chert
5,690 Black shale
5,695 Dark gray shale
5,703 Dark gray gritty limestone
5,725 Platy carbonaceous shale, nodular at base
5,730 Gray shale and limestone
5,735 Dark gray shale
5,748 Sandy limestone, grading downward to dense brown limestone
5,750 Black shale
5,760 Fissile gray shale and limestone. *Bucanopsis meekiana*
5,780 Fissile gray shale, with nodules of very dense granular limestone
5,804 Fissile gray shale, with a little brown shale
5,810 Variegated shale, very fissile
5,820 Well bedded granular dolomite
5,825 Granular brown dolomite
5,830 Reddish brown platy shale, chert pebbles, salmon-colored. Pebbles well worn
5,835 Sandy dolomite and dark brown shale

MISSISSIPPIAN, CHESTER

SECTION 16

Section 16 is not on the cross section, but it is important as regards the conditions of sedimentation. Three wells were necessary in order to obtain a complete Cherokee section. There is no Marmaton present. The Kansas City rests on the Cherokee, and the Cherokee probably on

granite. These wells show much arkose of different types. The conditions indicated by the samples are discussed later.

SECTION IN W. E. AND W. R. RAMSEY'S STATE NO. A-2, NE. 1/4, SW. 1/4, SW. 1/4 SEC. 21, T. 5 N., R. 5 E., CIMARRON COUNTY, OKLAHOMA

Elevation, 4,000 feet

BEDS OF LOWER KANSAS CITY AGE

BEDS OF CHEROKEE AGE

3,935-3,945	Brown shale
3,955	Gray and brown shale and marl
3,967	Brown shale and some gray shale
3,977	Buff limestone. *Fusulinella* sp., *Aulopora* sp.
3,982	Brown shale
3,995	Gray and brown shale and limestone shells
4,025	Glauconitic limestone and maroon shale. *Climacammina* sp., *Chaetetes schucherti ?*, *Fusulinella* sp. (has straight septa)
4,033	Gray micaceous fine sandstone
4,037	Brown shale
4,050	Calcareous micaceous gray gritty shale
4,060	Gray and brown shale and limestone shells. *Rhombopora* sp., *Cytherella* sp.
4,078	Little pink arkose at top; remainder is fine angular calcareous sandstone
4,095	Maroon shale
4,096	Red limestone. *Rhombopora* sp. (very plentiful), *Jonesina* sp.
4,100	Maroon shale
4,109	Fine micaceous red sandstone
4,112	Maroon shale and dense limestone. *Chaetetes* sp., *Rhombopora* sp.
4,118	Maroon shale
4,120	Sandstone
4,131	Maroon shale, much veined by limestone which has satin spar structure. *Climacammina* sp., ostracods
4,148	Maroon shale and limestone. *Fusulinella* sp. cf. *F. meeki*, *F. distenta*, and *F.* sp.
4,158	Maroon shale
4,166	Gray shale, veined by limestone as above. *Ambocoelia plano convexa*, *Choenetes* sp.
4,176	Maroon micaceous grits
4,182	Granular glauconitic limestone
4,193	Maroon micaceous grits. *Fusulinella minutissima*, *F.* sp., *Chonetes mesolobus*
4,208	Alternating maroon shale with limestone shells
4,216	Gray micaceous limestone
4,220	Maroon micaceous grits
4,229	Gray granular limestone. *Healdia* sp., *Fusulinella meeki*, *F. distenta*, *F. hartvillensis*
4,234	Gray micaceous shale
4,241	Nodular dark gray limestone, resinous, and some chert

SECTION IN W. E. AND W. R. RAMSEY'S STATE C-1, C. W. L., SE. 1/4, SE. 1/4, SEC. 4, T. 5 N., R. 6 E., CIMARRON COUNTY, OKLAHOMA

Elevation, 3,830 feet

BEDS OF CHEROKEE AGE

	Near base of State A-2
3,930-3,935	Calcareous arkose. *Fusulinella meeki*

3,955 Alternating gray and maroon shale
3,960 Speckled sandy limestone. *Fusulinella meeki*, *F.* sp. cf. *F. meeki*, *F. minutissima*, *F. hartvillensis*
3,970 Gray and maroon shale with limestone shells
3,983 Light and dark gray micaceous sandy shale with limestone, shell at base. *Rhombopora* sp., *Chonetes* sp.
4,015 Dark gray micaceous shale
4,020 Gray shale
4,036 Dark gray micaceous shale
4,038 Calcareous arkose
4,050 Granular limestone and gray gritty shale
4,055 Pink arkosic conglomerate. Different types of igneous rock
4,063 Gray shale, calcareous sand, and white limestone. Crinoids
4,110 Black slivery shale
4,129 Gray greasy shale with some sandstone
4,135 Black shale with dense buff limestone shells
4,144 Shale
4,152 Arkosic limestone. *Fusulinella minutissima*, *F. hartvillensis*, *F.* sp.
4,164 Dense brown limestone and gray-green shale
4,168 Pink arkosic conglomerate. One type of igneous rock
4,180 Gray-green shale and pink arkose

SECTION IN W. R. AND W. E. RAMSEY'S STATE A-1, C., NW. 1/4, SW. 1/4, NE. 1/4, SEC. 27, T. 5 N., R. 5 E., CIMARRON COUNTY, OKLAHOMA

Elevation, 3,943 feet

BEDS OF CHEROKEE AGE

Near base of State C-1
4,380-4,386 Dark gray shale and some green shale
4,391 Dark limestone and gray shale. *Chonetes mesolobus*, *Chaetetes milleporaceus*, *Fusulinella* sp., *F. coloradoensis*
4,421 Gray limestone and gray shale
4,426 Dark gray shale and arkosic sandstone
4,432 Black shale and grits
4,437 Arkose
4,442 Gray shale
4,450 Black shale
4,460 Black shale. *Chonetes* sp., *Roemerella patula*
4,476 Gray limestone
4,480 Black shale
4,485 Gray to black shale with some limestone
4,490 Dark gray shale
4,500 Black shale and limestone, very fossiliferous. *Ambocoelia planoconvexa*, *Chonetes mesolobus*
4,512 Gray limestone and shale
4,522 Cherty gray limestone. Sponge spicules
4,528 Gray limestone and gray shale. *Fenestella* sp.
4,540 Granular gray limestone
4,544 Gray shale
4,552 Limestone and black shale. *Fusulinella* sp., *F. distenta ?*, *F. coloradoensis*, *F. rockymontana*, *Amphissites* sp.
4,574 Dark maroon shale and pink arkose
4,580 Dark maroon shale and salmon-colored chert. *Fusulinella distenta*, *F. rockymontana ?*, *Bradyina* sp. cf. *B. holdenvillensis*, *Climacammina* sp.
4,585 Maroon shale and gray limestone
4,598 Gray-green shale and gray limestone. *Marginifera* sp., *Roemerella patula*
4,606 Granular limestone and chert

4,617 Dark gray shale. *Lingula carbonaria*
4,622 Gray shale and limestone with a green cast
4,630 Sandy limestone, arkosic, and gray and brown shale
4,635 Dark gray micaceous shale
4,640 Limestone and green carbonaceous shale
4,650 Limestone and black shale
4,656 Dark micaceous shale
4,662 Black gritty shale and limestone shells
4,670 Maroon shale and arkose
4,681 Fresh pink arkose. No particles show weathering or attrition; probably is granite

PRE-CAMBRIAN
Granite

SECTION 17

Section 17 is part of the log of the Phillips Oil Company's Andrews No. 1, Colorado. In this section the Kansas City rests on the Cherokee at 4,660 feet. The base of the Cherokee has not been encountered. It is very rich in fusulinids and shows close affinities to the Hartville section.

SECTION IN PHILLIPS OIL COMPANY'S ANDREWS NO. 1, SEC. 3, T. 2 S., R. 42 W., YUMA COUNTY, COLORADO
Elevation, 3,443 feet

BEDS OF LOWER KANSAS CITY AGE

BEDS OF CHEROKEE AGE
4,660-4,680 Dense buff limestone. *Fusulinella euthusepta ?* This is a Cherokee form, but the exact identification is somewhat in doubt
4,690 Gray-green granular shale and marl
4,710 Gray granular limestone with some gray shale
4,715 Green-gray shale with granular limestone and pink shale. *Bairdia* sp.
4,720 Gray sandy limestone
4,735 Dark sandy limestone and gray shale. *Triticites* sp. (cave), *Fusulinella hartvillensis*, *F.* sp. (two)
4,750 Dark gray gritty and maroon shale. *Tetrataxis* sp., *Climacammina* sp.
4,760 Maroon and carbonaceous shale with limestone. *Ambocoelia planoconvexa*
4,765 Limestone
4,775 Micaceous gray and maroon shale. *Fusulinella* sp., *F. minutissima ?*
4,785 Dense limestone, gray shale shells
4,792 Gray grits, micaceous. *Fusulinella* sp. fragments
4,805 Gray and maroon grits with limestone shells. *Fusulinella* n. sp.
4,815 Limestone and maroon grits *Fusulinella minutissima*
4,825 Translucent chert and gray granular limestone. *Fusulinella* sp.
4,835 Gray granular limestone
4,840 Gray granular limestone and maroon shale
4,850 Gray grits and black and maroon shale
4,860 Dark gray and maroon shale
4,865 White limestone
4,870 Dark gray shale and limestone
4,875 Fissile dark gray shale
4,880 Dark gray-green shale

4,905 Fissile dark gray shale, with alternating green and brown streaks. Gastropods, *Ambocoelia planoconvexa*, *Fusulinella* sp., *F.* sp., probably *F. meeki* var. *tregoensis*. These *Fusulinellae* closely resemble the Hartville of Wyoming, Sec. 8, T. 30 N., R. 68 W.

Total depth 5,130 still in Cherokee

REGIONAL CONSIDERATION

From the evidence of well samples and outcrop sections it is possible to outline conditions prior to entrance of the Cherokee sea. In almost the whole area there is evidence of a great erosion period which brought the terrain nearly to a base-leveled condition. All of the pre-Cherokee sediments are folded and in certain areas show complex folding. It seems that during the pre-Cherokee erosion period a basin was in existence in the area that is now southeastern Oklahoma and an area of undefined limits in adjacent parts of Texas and Arkansas. This basin received sediments probably continuously from late Mississippian to Pennsylvanian time. These sediments were derived in part from the northwest, north, and northeast. They formed what is known as the Chester, of Mississippian age, and the Morrow, which contains some residual Mississippian forms of life and many proemial Pennsylvanian forms. The Morrow is pre-Pottsville in age. It is the only stratigraphic division so far discovered that seems to fill, in part, the gap between deposits of well established Pennsylvanian and Mississippian ages.

Above the Morrow, and seemingly more restricted to the southeastern part of Oklahoma, are sediments of Pottsville age, such as the Winslow or early Atoka. The break between the Pottsville and Allegheny is not apparent in southeastern Oklahoma and sedimentation was probably uninterrupted up to and including Kansas City time and perhaps somewhat later.

The northwestern shore line of this early Pennsylvanian sea may be marked by the extent of the Wapanucka, but how much of the original Wapanucka has been eroded can not be determined. However, this sea did not extend northwest very far. It probably did not reach Oklahoma City. The whole region northwest of Oklahoma City was a land mass. Near Oklahoma City are sediments ranging from Canadian (of Ulrich) to Meramecian (Mississippian) which were upturned and beveled. In Harper, Woods, and other counties of northwestern Oklahoma and in southwestern Kansas, a large area of Chester was exposed which marks a second Mississippian basin in that part of the country. It may also have received sediments of Morrow age, which have subsequently been removed; however, this is the only area outside of southeastern Oklahoma which again might have bridged the gap between the

Pennsylvanian and Mississippian periods of sedimentation. This general Mississippian basin extended to Hamilton County, Kansas.

From this basin northward the pre-Pennsylvanian and other beds are found dipping gently south. The beds contained minor irregularities with probably 200 or 300 feet as a maximum relief. Beds are encountered ranging from Osage, through Kinderhook, to and including Ordovician, such as Galena and Simpson; also Canadian or Ozarkian, and down to the Cambrian or Deadwood in the northwestern part of Kansas.

It seems that this area in Kansas and part of Nebraska was subjected to more or less tropical conditions which formed a surficial deposit of laterite, similar to that of the present tropics. Plant remains are plentifully preserved in the sediments. As the region had practically no relief, no coarse sediments were contributed to the Pennsylvanian sediments, which were to come. The evidence in western Nebraska is very scanty, as no wells have been drilled through the Pennsylvanian.

In the Black Hills of South Dakota erosion had not progressed as far as it had farther south. Everywhere the Pahasapa underlies the Pennsylvanian and evidently has not been much eroded. The topography was comparatively level, and it seems that here, too, a tropical or humid condition existed, as the early Pennsylvanian sediments are considerably discolored by red shales.

In southeastern Wyoming the same conditions were noticed, except that erosion had almost passed through the Guernsey formation, which is the same as the Madison and the Pahasapa. This region also was so flat that it received even less sediments of a clastic nature than did the Black Hills when the Cherokee sea advanced upon the area.

In Colorado, the pre-Pennsylvanian sediments are very complexly folded and exhibit considerable relief; that is, granites and sediments ranging from Mississippian to pre-Cambrian time are exposed. The highlands were probably somewhat east of the present Front Range of the Rocky Mountains. The pre-Pennsylvanian topography of southern Colorado, northern New Mexico, and part of the Panhandle of Texas had considerable relief and much of the surface was granite.

This gives a general idea of conditions previous to the entrance of the Cherokee sea. Briefly, there was a basin receiving sediments in southeastern Oklahoma, another basin evidently extending across the northwestern part of Oklahoma into southwestern Kansas, which was not receiving sediments at that time, and a vast area extending across Kansas, Nebraska, and South Dakota of practically no relief and contributing few sediments. The area, extending from southwestern Wy-

oming, across the central part of Colorado and into New Mexico, contained highlands, which were either actually high or were being subjected to rapid erosion,—the latter is more probable.

Upon these conditions the Cherokee seas advanced, evidently with great rapidity. They probably came in largely from the south, west, and east. Deposition was extremely rapid in certain areas, especially in the southeast and southwest. Sediments about 20,000 feet in thickness were deposited in the Ouachita geosyncline during this time. The sediments filling a large part of the Ouachita geosyncline came from the southeast and were deposited as an enormous river delta, somewhat similar to the delta of the present Mississippi. Fragments found in various conglomerates of early Cherokee age deposited in the Ouachita geosyncline were derived from materials which crop out only at the south and southeast. For example, fragments of Talihina chert occur in lower Atoka and in the southwest conglomerates, fragments of Arbuckle limestone, that is, Canadian and Ozarkian, occur with fragments of the various limestones composing the Hunton terrain. These sediments contained large quantities of plant fragments, such as logs. The effects of these deltaic deposits, which were shales, some sandstones, and a few pronounced limestones, extended as far northwest as Oklahoma City.

In Kansas, most of the Cherokee is very thin, and in places is absent, because of minor irregularities previously mentioned. Sediments of Cherokee age are largely composed of red shales, variegated shales, and cherts, containing plentiful plant remains, thus showing that vegetation was very extensive. There is an absence, except at the base, of the more clastic sediments.

In Nebraska, southeastern Wyoming, and western South Dakota, limestones predominate, indicating the absence of very active erosional forces. Probably this general area sank to considerable depth relative to the region in western Kansas.

In central Colorado active deposition was taking place, evidenced by the predominance of arkosic sandstones and massive conglomerates. This rapid deposition also extended to the Cherokee sediments of Cimarron County, Oklahoma, inasmuch as here several beds of arkose are present. However, sediments of a coarse conglomeratic nature evidently did not reach this region. In the northeastern part of Colorado, conditions during Cherokee time were somewhat similar to those in western Kansas, except that the Cherokee is thicker, and most of the material is red and gray shale containing much carbonaceous material, and some limestone.

Conditions of deposition continued through the Marmaton, which, however, did not extend as far northwest as the Cherokee. Sediments of definitely Marmaton age were not identified in the Panhandle of Oklahoma, in Colorado, Wyoming, and South Dakota. It seems that there was some erosion in this general region before early Kansas City time.

The Kansas City seemed to cover most of the area,—at least, the lower part did, as some of the limestones in the upper Hartville of Wyoming contain a *Triticite* oölite, which resembles in every respect a *Triticite* oölite found in the Drum limestone of Kansas. This oölite has also been found in Cimarron County, Oklahoma, and in the Phillips well drilled in Yuma County, Colorado. An erosion period followed this deposition, which occurred at the time of the Arbuckle and Wichita uplifts and was pronounced in some areas.

PENNSYLVANIAN CLIMATES AND PALEONTOLOGY[1]

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ABSTRACT

For a half century or longer, the general conception of Pennsylvanian climate has been that of a mild, tropical, or almost tropical, humid condition of world-wide extent. Although this conception results in part from the Laplacian hypothesis, it results mainly from the interpretation of certain characters of the floras and faunas of the period. These characters are summarized as follows: large size of Pennsylvanian insects, coral reefs in Spitzbergen, climacteric development and wide distribution of benthonic *Foraminifera*, cosmopolitanism of floras and faunas, many structural features of the plants, and stagnation of evolution. A survey of the recent literature on the possible climatic implications of these characters does not support the contention that they imply the kind of climate that they have been represented as postulating. Although some of the faunal and floral characters apparently have no climatic implication whatever, other characters cited as evidence of warm climate imply the reverse. Some characters of supposed climatic significance indicate merely environmental conditions, such as local water temperatures, warm currents, or swampy surroundings, having little or no climatic significance. Certain characters preserved in organisms from the Pennsylvanian to the present are commonly interpreted as having climatic significance because the contemporary organisms with these characters are adapted to certain climatic conditions. However, this interpretation disregards entirely the possibility of adaptations during the vast span of time subsequent to the Pennsylvanian.

The general conception is that the Pennsylvanian (Upper Carboniferous) period was characterized by a very humid, tropical climate. For example, White concludes that "the climate of the principal coal-forming intervals of the Pennsylvanian was mild, probably near-tropical or sub-tropical, generally humid and equable."(1)[3] Although this idea results in part from the Laplacian or Nebular hypothesis of the origin of the earth and its subsequent slow cooling, it is mainly the result of the interpretation of certain characters of the floras and faunas of the period. Few attempts have been made to interpret the possible climatic significance of the physical features of the Pennsylvanian.

Almost 20 years ago some geologists began to doubt the prevalent opinion concerning Pennsylvanian climate (2), and in the past few years

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[3]Numbers in parentheses indicate references at end of paper.

several geologists and the English climatologist, Brooks, have studied the problem chiefly from a standpoint other than paleontological, and their conclusions are at variance with the general notion of Pennsylvanian climate (3). Inasmuch as the climatic implications of the physical evidence are undoubtedly difficult and elusive to interpret, their evaluation has been neglected; the biologic evidence which seems easily interpreted has been used for the past half century, or longer, as the basis for assigning world-wide tropical or subtropical conditions to the Pennsylvanian. The biological criteria which seem to indicate that the Pennsylvanian was a period of "warmth throughout" have recently been summarized by Dunbar, as follows.

1. The large size of Pennsylvanian insects wherever found.
2. The occurrence of coral reefs as far north as Spitzbergen.
3. The climacteric development and wide distribution of the large, benthonic *Foraminifera* of the *Fusulina* group.
4. The cosmopolitan character of both land floras and marine faunas.
5. Many structural features of the luxuriant and abundantly preserved coal-measures plants.
6. The long duration, with slight changes, of both faunas and floras,—a condition sometimes described as "stagnation of evolution"(4).

The determination of the character of the climate of a geological period, recent or remote, is extremely difficult. Although during recent years the subject of paleoclimatology has caused much interest, results attained are little more than broad generalizations applied to vast areas of the earth's surface, or to the world as a whole, for long periods of time. Unless there is evidence to the contrary, such as tillites, it is assumed that a generally mild and equable climate persisted in large parts of the earth during periods of time estimated in millions of years.

The possibility of climatic variation from place to place and fluctuation during a geologic period is seldom considered unless evidence indicates extreme conditions such as widespread aridity, glaciation, or widespread changes in life. The indefinite and intangible geologic evidence remaining from slight climatic changes is an explanation of this condition. Another explanation of the geologist's seeming neglect of the recognition of climatic variation and changes is the inadequate knowledge of the causes of climatic fluctuations.

The causes of the supposed profound changes in the earth's climate from general and mild equability to rigorous aridity or glaciation have caused much speculation. The English meteorologist, Brunt, concluded his recent text on meteorology with the statement that the problem of variation of climate "is one which has produced a vast amount of literature,

much of which is of little permanent value"(5). Much has been written by geologists, for they, rather than climatologists or meteorologists, are primarily concerned with the evidences of climatic fluctuations during geologic time. But the fact that much of this literature is very speculative and insecurely founded is not to be attributed entirely to deficiency in observation or inadequate knowledge on the part of the geologist. Only in the last few years have climatologists or meteorologists attempted to summarize adequately the operation of climatic controls, and there is yet disagreement as to the relative efficacy of these controls in producing climatic changes. Some scientists attribute the fluctuations mainly to variation in atmospheric conditions, others to terrestrial changes, and a third group attributes the fluctuations to the more elusive and speculative cosmical controls.

The present trend, however, seems to place increasing emphasis on the operation of strictly geographic controls. Humphreys concludes his discussion of climatic controls thus.

> It appears from various considerations that, with a constant or nearly constant output of solar energy, the earth itself possesses the inherent ability to profoundly modify its own climates, whether only local or world-wide (6).

The climatic changes are attributed to the effects of latitude, land distribution and elevation, topographic inequality, continental expansion, volcanism, diastrophism, distribution, direction of flow and temperature of ocean currents, expansion of oceanic areas over the continental segments, and the character of surface covering. Although these controls, operating singly or in conjunction, may not be the fundamental factors in producing pronounced or long-continued climatic changes, they undoubtedly profoundly modify climate of small and large areas for long periods of time.

The geologist is also confronted with the difficulty of insufficiency of knowledge. If there were general agreement as to the operation of climatic controls, and their causes and effects were thoroughly understood, nevertheless the geologist has the difficult task of applying this knowledge to indefinite, scattered, and imperfectly preserved physical and biologic vestiges from a sequence of events that occurred in a very remote time, in Pennsylvanian time, for example, probably more than 150,000,000 years ago. Obviously, the reliability of the conclusions depends on the accuracy of interpretation of climatic factors and the completeness of knowledge of the sequence of events in the remote past. After the operation of climatic controls is correctly interpreted, the facts regarding land distribution and elevation, volcanism, diastrophism, dis-

tribution of ocean currents, et cetera, of the Pennsylvanian, or any other geologic period, must be thoroughly understood if other than merely a broad and indefinite generalization concerning the climate of the time is to be obtained. Inasmuch as adequate and complete knowledge of the geographic details of any geologic period is not available, the interpretation of the climatic conditions of the period can be only as detailed as the extent of the knowledge of the geography of the period permits. This is one of the chief reasons that the operation of climatic controls has been neglected in paleoclimatology, and reliance has been placed on the paleontologic record.

Unfortunately the paleontologic record for any period is far from complete, because of the lack of preservation of the full life sequence of the time and insufficiency of knowledge of what has been preserved. For example, the upland vegetation of the Pennsylvanian is unknown, and the climatic interpretation has been based chiefly on the plant record of a special habitat, a swamp environment.

A fundamental biological principle is that environmental factors determine the size of the individual, the number and kind of species, and the geographic and geologic range of a fauna or flora. Although climate is an important environmental factor, it should not be stressed to the exclusion of other factors. The characters of faunas and floras should not be used in making climatic inferences without consideration of other environmental factors that may have been instrumental in the production of the characters present. There is also the danger of deducing too broad and sweeping generalizations from floral and faunal characters. Therefore, the presence of a supposedly warm-water fauna should not be used to support the idea that adjacent lands were warm or that broad continental expanses were warm. Corals are often cited as evidence of warm climates, but in January several years ago the writer collected excellent specimens of branching coral on Virginia Beach; the air temperature, however, was considerably below the freezing point. Although warm-water forms are found on the Maine coast, that fact can not readily be used as an argument that Maine has a subtropical climate. Likewise, a warm-water fauna in the Mississippi Valley gives little indication of the type of climate of the Rocky Mountain region of the same time.

In 1929, A. L. Reading, the Canadian explorer, reported the results of dredging operations in Wager Bay, a northwestern extension of Hudson Bay, located south of the Arctic Circle. The dredgings yielded fragments of red coral of tropical appearance, and starfish, clams, and sea shells similar to forms in Florida waters. Jelly-fish 5 feet in diameter

were reported, so large that they could be seen in the water from an airplane at an altitude of 2,000 feet (7).

It is not certain that all of the so-called "warm-water faunas" lived in warm waters. The "desert areas" in the present oceans are in tropical regions, probably due in part to the lack of nitrogen resulting from the activity of denitrifying bacteria in warm waters. There is no paucity of life in the Arctic; although cold seas may be rich in life, their faunas probably contain fewer species than faunas of warm waters. Kirk has described a fauna profuse in species and individuals, both animals and plants, dredged from cold waters south of Alaska where icebergs are plentiful (8). He describes a similar elaborate fauna crudely dredged almost a century ago, north of 74°, where the temperature of the water is never more than 30° F. Kirk, in studying the faunal lists in the reports of the British National Antarctica Expedition, found 275 genera and 455 species exclusive of plants, vertebrates, worms, and minor types. In total number and in variety of species the list may be compared favorably with any Paleozoic fauna of Europe and North America, although most of the forms were obtained by dredging through holes in the ice, when the water temperature was below 0° C. The presence of aviculopectens, productids, and delicate fenestellids might be considered proof of a warm-water habitat, but at West Maitland, Australia, such an association is reported with striated boulders deposited by thawing icebergs on the surface of accumulating sediments (9). Schuchert emphasizes the fact that many marine forms of supposedly warm-water affinity persisted through the Permo-Carboniferous ice age in the waters of Tethys in the Indian region (10), although these waters, located in a region supporting ice sheets of vast extent, must have been perceptibly chilled.

It is very doubtful whether widely ranging marine faunas possess any climatic significance. They certainly can not indicate the climates of the land masses, or furnish evidence of average water temperatures. They may, however, indicate the distribution of warm currents; for example, a warm-water fauna in Spitzbergen may indicate the presence of a warm current with equatorial connections rather than a tropical polar region. The cold-water faunas of the southern hemisphere of to-day seem to be as widely distributed as the so-called cosmopolitan Paleozoic faunas of the northern hemisphere (11). Animals readily adapt themselves to changing environment and easily change habitat. They increase or diminish with changing food supply, they respond to increasing salinity or to augmented turbidity, but the influence of temperature changes on marine life seems subordinate to other environmental factors.

The distribution of marine life is controlled, as Kirk states, by available routes of travel rather than by temperature.

Land animals are more responsive to climatic changes than marine forms. However, organisms are readily and rapidly adaptable to changing climatic conditions, as emphasized by Scott.

> Similarly, the interglacial mammalian fauna which occurs at Afton, Iowa, is decidedly suggestive of a warmer climate than the present for the region involved. In this case, however, the evidence is less convincing, for the habits of extinct species of mammals can only be conjectured, and, as in the famous case of the Siberian mammoth, some ludicrous mistakes have been due to inferences concerning the climatic adaptations of extinct species, reasoning from the distribution of their existing allies (12).

Plants are ordinarily considered as reliable climatic indicators. In some conditions they may be reliable; in others, quite unreliable. Although the crow-berry, harebell, mountain sorrel, and yellow poppy might be considered adapted to cool temperate conditions, their abundance in Greenland during the summer months indicates an equally ready and complete response to subarctic conditions. Ample evidence also proves that closely related forms do not always show similar responses to climatic and other environmental conditions.

Adaptation to changing environment may readily occur. For example, alpine plants in the eastern United States have become adapted since the retreat of the Wisconsin ice sheet. In fact, the advance of the ice, accompanied by arctic conditions, not only forced the migration of plants southward in Europe and North America, but also indirectly caused adaptations to new environmental conditions. The plants established in a new environment persisted during the subsequent amelioration of climate succeeding the Pleistocene; therefore, many plants now found in Greenland are known in North America, the British Isles, Europe, Africa, and the Far East (13).

There is also danger of using floral characters for too broad climatic generalizations. The presence of a tropical or subtropical flora, or structural features common to tropical or subtropical plants, should not be used as evidence that the continent or the latitude, therefore, had a tropical or subtropical climate. The flora may be limited to an area having warm winds or protecting uplands. The "cosmopolitan" Pennsylvanian flora is generally considered an indication of mild conditions in polar regions, but Berry believes that the botanical characters of the arctic plants of late Devonian, early Carboniferous, late Triassic, late Jurassic, early Cretaceous, late Cretaceous, and late Eocene do not "support the tradition that there was ever a tropical or subtropical climate in polar regions"

(14). All show evidence of climatic zonation, particularly the Eocene flora. All the floras are of temperate types and are contemporaneous with times of continental sinking and oceanic expansion. Inasmuch as they have probably extended their range from lower latitudes toward the poles along protected lowlands favored by warm moist winds, they indicate a local northward swing of the annual isotherms throughout a few degrees of latitude rather than broad northward migration of the isotherms.

Concerning the use of plants as climatic indicators, Seward has recently stated:

> We know that closely allied species often grow in regions differing considerably in mean temperature. A further point is, ought we to assume that plants have remained unaltered in their constitution, in the sensitiveness of their living protoplasm, to the effects of cold and other external influences? It is surely rash to assume that in the course of ages there has been no change in the degree of response to factors which govern existence. My own view is that the practice of employing plants, especially extinct plants, as guides to temperature in the past, has been carried too far (13).

It seems evident that attempts to evaluate climatic changes quantitatively from the fossil records of the rocks are wholly untrustworthy.

With the preceding elementary considerations in mind, there remains the task of attempting the evaluation of the biologic evidence in order to determine whether it permits an interpretation other than the implication of mild and humid tropical or subtropical climatic conditions of world-wide extent for the Pennsylvanian.

1. *The large size of Pennsylvanian insects wherever found.*—Insects are not known previous to the Pennsylvanian, but it is probable that their ancestry goes back into the Devonian. In the early Pennsylvanian they were scarce and of moderate size, but during the period they deployed rapidly, generated more than 1,000 species, and developed enormously in size, the largest known land insect being the Paleozoic dragonfly, *Meganeura moneyi*, measuring 28 inches across its wings, but weighing probably only a few ounces. These ancient insects (*Paleodictyoptera* and their immediate successors) were the ancestral stocks of cockroaches (*Blattoidea*), dragonflies (*Odonata*), grasshoppers (*Orthoptera*), and related forms, classified in approximately 12 orders, representing essentially an *Orthoptera-Pseudoneuroptera* assemblage. Kennedy, in several recent studies bearing on the evolution and environment of the early insects, has come to conclusions of great interest to the student of paleoclimatology. He states:

> This sudden development of size was not due to the tropical conditions.

as suggested by Handlirsch, nor was it due to the primitiveness of the group, as suggested by Chetverikov, for the very first of the Carboniferous insects were not such giants. This development of size in the later Carboniferous insects was but the expression of evolution in insects similar to that in many other land animals, where the first specialization after a new group has been established is that of greater size. The increase in size gives greater weight, which, in a moving body, through the increased moment, weight times speed, greatly increases the power of the animal in securing food or in warding off enemies. Through some, at present unknown, quality of the germ plasm an increase in size is one of the most easily attained specializations. This phase in the evolution of a group, however, is usually transitory, as the giants are superseded by smaller, more active, and more versatile forms (15).

The tendency toward rapid increase in size in the early history of a group is excellently illustrated in the history of the primitive mammals of the early Tertiary, for example, the titanotheres, zeuglodon whales, and amblypods. As was true of the insects, their rapid specialization is of no climatic significance. The same tendency is seen in the early Mesozoic reptiles, and in the birds of the early Tertiary.

The work of Kennedy on insects, however, is of great climatic significance in other directions. He finds that modern species have a higher metabolic rate, faster physiological processes, swifter movements, and more pronounced preferences for bright sunlight and the warmer parts of the earth than had the ancient species. He believes that the tastes of the old-fashioned insects, "surviving fossils," are exactly the opposite. They develop their maximum numbers in the cooler parts of the earth, fly in the cooler parts of the day, or lurk in the shady woods or dark crevices, and are most active in cooler seasons (16). These insects include the stoneflies, mayflies, thrips, booklice, and the lower families of the grasshoppers, moths, and flies. They live long, breed but once a year, as a rule, and require several years to mature. One primitive genus, intermediate between crickets and cockroaches, requires 3 years to mature, and must be cultivated on ice in a refrigerator. The curves drawn by Kennedy, showing geographical distribution of the *Anisoptera* (suborder of *Odonata*, dragonflies) in North and South America, indicate that the primitive genera are represented in largest number of species between 35° and 45° north latitude, and between 30° and 40° south latitude. From his studies of habits of surviving primitive insects, Kennedy questions whether the heat and light levels of Mesozoic climates and Mesozoic tropics were as high as they are to-day (17).

The abundance of insects during the Pennsylvanian has no greater climatic significance than has the size of the insects. Approximately 150 species are known as early Pennsylvanian in age, a number that has

continually increased during subsequent geologic time until at present, notwithstanding recent glacial climate, the number of species is probably between 2,500,000 and 10,000,000.

2. *The occurrence of coral reefs as far north as Spitzbergen.*—The presence of corals has long been a "stock argument" for warm seas, and because the seas were warm, therefore, it is concluded that the lands also must have been warm. Kirk has recently investigated this subject and his conclusions are given herewith (18).

An argument for warm seas constantly used is the presence of coral reefs in the past. These reefs are not impressive at best and should be used with caution. Bonney, Yakolew, and others have pointed out that there is little real analogy between Paleozoic and recent coral reefs. As a rule the most important constituent of the Paleozoic reefs is *Stromatoporoidea*, while next in importance come the *Tabulata* and finally the *Tetracoralla*. These proportions vary, but as an average they probably hold good. Of the three groups the *Tetracoralla* alone may be compared with the reef corals of to-day, and even here the kinship is so remote that it would be rash indeed to insist on similar conditions of life. Rather, it is better to consider the bathymetric and temperature ranges of modern corals. We have already noted the presence in the freezing waters of McMurdo Sound of a cup coral, and we know that similar corals range down to a depth of 5,000 meters. Of even greater interest is the presence of large numbers of colonial corals along the European coast. The distribution of these forms has been summarized by Pratje ("Korallenbanke in tiefem und kuhlem Wasser." *Centralbl. für Min. Geol. u. Pal.*, No. 13 (1914), pp. 410-15). He shows that the four species belonging to the genera *Lophohelia*, *Amphihelia*, and *Dendrophyllia* referable to the families *Oculinidae* and *Eupsammidae* are living to-day as far as 71° north latitude. Off the coast of Norway the bathymetric range of the corals is from 200 meters to 600 meters. Off the Irish, French, and Spanish-Portuguese coasts the optimum depth appears to be somewhat the same, but a downward range to at least 1,800 meters is known. The seaward range of the corals seems to coincide approximately with the edge of the continental shelf. Off the Norwegian coast with an adverse factor of high salinity the northern limit seems to be conditioned by low temperature. The minimal temperature, however, is 6.6° C. If the *Tetracoralla* and *Tabulata* of the past must be considered as requiring temperature and bathymetric conditions like those of present-day corals, we have a wide range of both to choose from.

3. *The climacteric development and wide distribution of the large, benthonic Foraminifera of the Fusulina group.*—Climatic inferences from the widespread and uniform distribution of phyla, large size of individuals, or slight faunal changes through thick series of sediments, may be significant, but should not be considered conclusive. Such faunal characters may indicate uniform environmental conditions persisting in wide areas during long periods of time, but possess no climatic bearing whatever. The normal history of a phylum, as repeatedly revealed in historical

geology, is ascendancy to climacteric development followed by decline. To attribute that history to climatic conditions only, is to ignore completely other environmental factors that unquestionably are significant in the normal history of phyla.

Inasmuch as the geographic distribution of organisms "is primarily controlled by available routes of travel," a knowledge of the paleogeography of a geologic period is indispensable in interpreting the significance of faunal and floral distribution during the period. Little is known of the geography of geologic periods, and the best paleogeographic maps are hypothetical and merely suggestive. There seems to be, however, somewhat general agreement that during the Pennsylvanian the northern hemisphere was characterized by an extensive land mass (Eria-Angara), and the southern hemisphere by two land masses, Gondwana and Antarctica, with land areas much more extensive than to-day in both hemispheres (19). If such a land distribution existed, it must have had great climatic significance; however, only Brooks has studied this phase of the general problem of the character of Pennsylvanian climates. A mediterranean sea, Tethys-Caribbean, occupied much of the equatorial region, constricted between Eurasia and Gondwana, and between North and South America, expanding farther northward and southward in the Pacific than in the Atlantic. This sea must have been warm, because of its geographic position, although there were icebergs in it in the Indian-Australian region in "Permo-Carboniferous" time. It sent its warm currents with their faunas northward and southward into indentations in Eria and Gondwana. Where these indentations continued through the continental masses of the two hemispheres, the currents were carried into polar waters. Exactly as the gulf stream carries warm surface life to-day into the cold north Atlantic Ocean, so these warm currents carried warm water life far northward and southward, the pelagic life out in the open currents, the shallow-water life near the shore lines of the indentations. Spitzbergen, for example, lay in the pathway of the Volga Sea, which opened broadly southward into Tethys, receiving warm currents from that direction. Warm waters at the surface were similarly carried northward between North America and Asia, and southward between South America and Australia. Therefore, indentations persisting during a considerable span of the Pennsylvanian would reveal the ordinary long-ranging warm-water faunas and evolutionary changes of local significance. Briefly, the distribution of marine invertebrate life in the Pennsylvanian, as it is to-day, was controlled chiefly by currents and by geography. Warm currents, warming adjacent lands, undoubtedly had a climatic in-

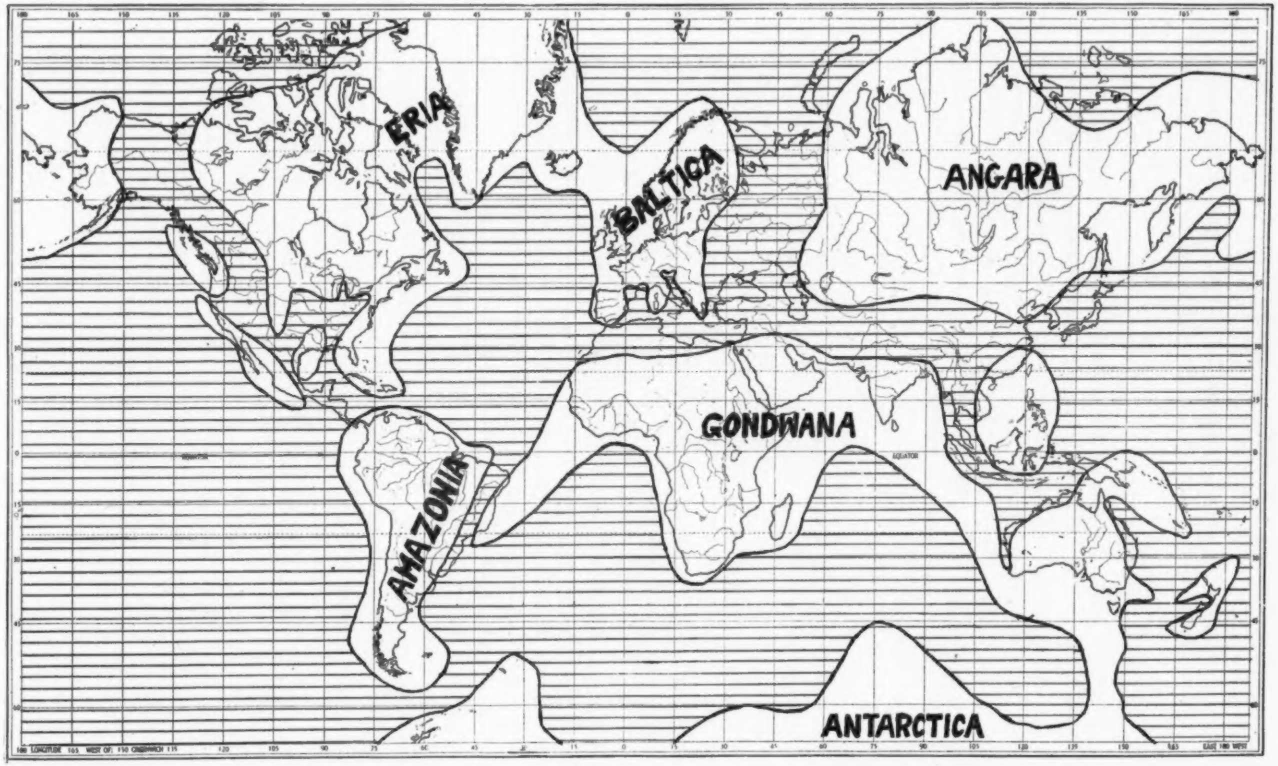

FIG. 1.—Paleogeographic map of Pennsylvanian (mainly from Schuchert's map of early Permian)

fluence, but with limitations; the warm Gulf Stream, for example, did not prevent the Pleistocene glaciation of the British Isles, or northwestern Europe.

4. *The cosmopolitan character of both land floras and marine faunas.* —Cosmopolitanism implies relative uniformity of environment in wide areas, together with intercommunicating routes of travel. Although it may be interpreted as implying tropical conditions, cosmopolitanism implies neither warm nor cold conditions. Pteropods are cosmopolitan in distribution in arctic waters, diatoms in the antarctic, and invertebrate faunas in the cold waters of the southern hemisphere. During the Pennsylvanian the great longitudinal extent of the equatorial Tethys-Caribbean sea promoted cosmopolitanism in low latitudes; the Pennsylvanian faunas of arctic and antarctic waters are not well known.

The "cosmopolitan character" of the earlier and later Pennsylvanian floras is generally cited as evidence of a warm, humid, and equable climate of world-wide extent during the period; however, the floras are little known, outside of Europe and North America (20), and were seemingly grouped near the north Atlantic embayment of the Tethys-Caribbean. Here, under the stabilizing climatic influence of this embayment, and the adjacent narrower Mississippi and Volga embayments, the floras developed luxuriantly, the warm mediterranean sea flanked by almost continuous land masses favoring rapid and wide distribution, longitudinally, of the Pennsylvanian floras. Favorable topographic conditions and equable winds also permitted the local extension of the Pennsylvanian floras into northern latitudes. Neither supposition, however, involves the postulation of universal tropical or subtropical climate extending into high latitudes, or requires excessive humidity, local or widespread.

5. *Many structural features of the luxuriant and plentifully preserved coal-measures plants.*—White has discussed the floral characters that seem to indicate tropical or subtropical conditions. They may be summarized as follows: large size and luxuriance of vegetation; succulent nature of forms; large cells, many with thin walls; large intercellular spaces; large fronds; large spongy leaves; stomata in grooves; profusion of drooping fronds and pendant branches to facilitate shedding of rain; smoothness and thickness of bark; absence of growth rings; delicate foliage in climbing lacinate forms; lacunose tissue and provision (hydathodes) for discharge of excess water; widespread occurrence of heterospory; provision for delayed fertilization and devices for seed flotation; development of sub-aerial roots; dilation of tree butts; development of pneumatophores; tendency to the development of flowers and fruits on

lower parts of stems and branches; presence in many ferns of *Aphlebiae*, unknown to-day except in tropical types; delicacy of fern-like lianas; presence of types adapted or confined to warm, moist, climatic conditions, their nearest present-day allies attaining greatest growth in warm, humid regions; and cosmopolitanism of flora with great radial distribution in latitude and longitude (21).

A different interpretation may be placed on most of the paleobotanical features presented as evidence of a tropical or subtropical climate during the Pennsylvanian. Arber maintains that the characters of the Carboniferous flora do not prove that the climate was tropical, inasmuch as luxuriant forests are found to-day in temperate regions and the large cells of the plants are not considered necessarily indicative of tropical conditions (22).

Many of the largest plants of the Carboniferous, such as *Calamites*, *Lepidodendron*, and *Sigillaria*, had narrow leaves, the small surface exposure to the sun being indicative of bright sunlight. The smaller and more shaded plants, such as the ferns and the cycad-ferns, did not have exceptionally large leaves, indicating that they received plenty of sunlight, although partly shaded. Although water is physiologically usable only in small quantities by plants, the leaves of many plants were supplied with various devices to prevent a too rapid loss of water by rapid transpiration. This might indicate aridity, or it might indicate a brackish-water environment in which plants had devices to prevent rapid transpiration as plants to-day have. White, however, believes the floras were halophytic. Most of the leaves of the trees were protected from too great effect of the sunlight by palisade cells on their upper surfaces. The presence of the thick corky bark of the Carboniferous plants has been interpreted as a pseudoxerophytic adaptation, and as a protective device against rigorous external conditions. The leaf scars are remarkably preserved, a fact interpreted by some to indicate extremely rapid growth and quick burial, and by others to indicate a texture very resistant to decomposition and an atmosphere unfavorable to decomposition because of its dryness and coolness.

The pseudoxerophytic characters of the Pennsylvanian floras, such as sub-aerial roots and dilation of tree butts, have caused considerable discussion. By some they are regarded as merely an adaptation to a swampy environment where there is an excess of water. White states that

> the so-called "pseudoxerophytic" features of swamp and bog plants whose roots extend near the surface and are normal to a wet footing are for the purpose of protection against destructive suffering on occasions of drought when the water level is unusually lowered, and that they are therefore really xer-

ophytic, finds abundant support in the paleobotanical criteria offered by the fossil swamps. The pseudoxerophytic characters appear to indicate probable subjection to occasional times of unusual evaporation (23).

A swampy environment alone might cause succulence of growth, large intercellular spaces, numerous hydathodes, presence of heterospority, flotation devices, provision for delayed fertilization, and similar characters.

The argument that the modern representatives of certain Pennsylvanian types are now confined to tropical regions loses much of its importance because the long period of time since the Pennsylvanian has permitted ample opportunity for "exterminative competition" in conflict with later higher types, and adaptations.

It is easy to over-emphasize the adaptation to tropical conditions of the modern descendants of the ancient types. In their abundance in the humid tropics, and in their large size gradually attained during successive generations in a year-long growing season, they surpass their more diminutive allies of temperate and arctic regions. Nevertheless, the descendants of the Pennsylvanian floras, namely, ferns, equisetae, club mosses, conifers, and related types, are to-day essentially world-wide in distribution. Campbell, in describing the flora of subarctic regions, emphasizes the fact that

a notable feature of these northern latitudes is the abundance of club mosses of the genus *Lycopodium*, most of the species occurring both in Eurasia and America. These are undoubtedly very old forms, and the same may be said of the horse-tails (*Equisetum*), and a number of wide-spread species of subarctic ferns (24).

It is possibly worth while to mention briefly that in the northern United States the sporophyte generation of the horse-tails is among the first plants to appear in the spring.

As Antevs has stated, the formation of rings depends on several factors, of which climate is only one (25). Some species do not form rings under any circumstances. Although conifers are likely to form rings, dicotyls are not so much so, but in conifers distinctness of rings varies with species. In some species ring development is a response to periodicity of wet and dry seasons, or to periodicity in nutrition. In general, growth rings are most marked in temperate regions, where absence of rings is exceptional. Rings in high mountain and arctic regions are ordinarily indistinct and possibly difficult to discern. In the tropics rings may be present or absent, depending chiefly on the species. Annual rings were present in Paleozoic, Mesozoic, and Cenozoic woods, but in Paleozoic woods growth rings were a primitive character and may have

required decided seasonal changes for their production. Briefly, Antevs concludes that absence of rings "does not signify uniform climate, and can not be given climatic significance." According to Jeffrey, the annual rings of the wood from the English Carboniferous are clearly marked (26). Goldring has described annual rings found in coniferous wood obtained from the Upper Pennsylvanian below the Americus formation of Oklahoma and from the Carboniferous of Pottsville, Pennsylvania (27). Knowlton has described nine species of *Cordaites* and *Dadoxylon* from the Pennsylvanian showing distinct and indistinct growth rings, seven obtained in latitudes south of England, three of which were obtained in Nova Scotia, and one in upper Alsace (28). Goldring states:

in the Carboniferous the development of distinctly marked annual rings of growth indicates a pronounced seasonal variation in the climate of that period even in far southern latitudes.

Much of the vegetation may have been of rapid growth, persisting only through the growing season. The lushness of the vegetation, the leaf scars expanded to large size in many forms, the pithy interiors of many forms, and the primitive character of the floras strongly substantiate this conception. Such forms, of course, would not be expected to show rings.

The pithy interiors of many of the plants of the time were not adapted for the preservation of growth rings. Their interiors are ordinarily found only as sandstone casts with bark impressions on the surfaces. The logs and branches are characteristically flattened. This would tend to destroy evidences of rings.

6. *The long duration, with slight changes, of both faunas and floras, —a condition sometimes described as "stagnation of evolution."*—Relatively short periods of climatic rigor are also periods of rapid organic evolution. Old stocks, no longer plastic, can not become adapted to rapidly changing geographic conditions and climatic stress; therefore, they disappear with remarkable abruptness. They are replaced by new stocks, plastic and adaptable, which deploy rapidly and undergo marked evolutionary changes. However, the longer periods of mild climatic conditions are times of widely distributed and long-ranging faunas and floras, times of so-called "stagnation of evolution." But a casual survey of the plant, vertebrate, or invertebrate life of the Pennsylvanian does not indicate any stagnation of evolution. In fact it would be difficult to find a geologic period in which faunal and floral changes were more rapid or more pronounced.

The rapid and important floral changes are summarized by White (29).

From a meager, stunted, and comparatively insignificant late Mississippian flora, there arose in the early Pennsylvanian a very rapid differentiation of land plants, most of which were at the beginning derived from two or three Neuropteroid and Triphyllopteroid genera.

This flora reached its maximum of luxuriance and elaboration in the middle and upper Pottsville. Significant plant changes in progress during the Alleghenian increase in importance in the Conemaugh and Monongahela, radically changing the general character of the flora. White states that the heterosporous lycopods rapidly disappear. At the same time there is a rapid increase in what are now temperate zones of gigantic tree ferns provided with "immensely thickened bark (including internal ramenta) with structural physiological provision for water storage"(30). The delicate membranaceous and clambering types almost disappear, and many of the plants develop thick pinnules with coriaceous or villous coverings. The lepidodendrons show a rapid decrease approaching extinction, the sigillarians wane, and one group of swamp environment develops thick bark. Other spore-bearing plants greatly decrease, and the more resistant seed plants, cycadaceous types, appear.

Knowlton has recently discussed the differentiation of the important group of conifers during the Pennsylvanian.

From the fact that the group became so firmly established and diversified in the succeeding Mesozoic era, the inference seems logical that it must have had its beginning in Carboniferous time, and this is probably true, though available facts on this point are not as conclusive as could be wished.

Probably the most distinctive of these supposed Paleozoic conifers is called Walchia....[which] was abundant and widely distributed during upper Carboniferous and Permian time, with somewhat questionable evidence that it persisted into Triassic time.

About a dozen other genera of probable conifers have been described from Upper Carboniferous and Permian rocks (31).

A detailed account of the floral changes can not be given in this paper, but it is evident that the Pennsylvanian was far from being a period of "stagnation of evolution" affecting the floras of the time. One finds, during this period, not only the appearance, rapid deployment, and disappearance of many ancient types, but the introduction of many new types, together with the firm establishment of the seed-bearing habit in several types, one of the most important events in the history of plants, foreshadowed in the seed-ferns as early as Upper Devonian. The rapid expansion in the later Pennsylvanian of the provision for re-

production by seeds undoubtedly has climatic significance, inasmuch as seeds may preserve their vitality through unfavorable seasons.

Evolutionary changes in the vertebrate world during the Pennsylvanian were profound and of far-reaching importance. Although the fishes, which had experienced a long evolutionary history previous to the Pennsylvanian, might be expected to show few changes in the Pennsylvanian or later periods, there were significant evolutionary advances, such as the remarkable decline of the shell-eating sharks, further adaptation to a fresh-water environment, change in body outline for swifter movement, and the beginning of differentiation of the teleosts from a ganoid stock in late Pennsylvanian and Permian.

Of all the vertebrates of the Pennsylvanian, the amphibians show the most remarkable changes caused by favorable swamp environment. Their remains, of great rarity previous to the Pennsylvanian, were somewhat rare also in the early Pennsylvanian, but later appeared in profusion. By the middle of the period the amphibians were differentiated into at least five orders (*Salientia*, *Lysorophia*, *Lepospondyli*, *Temnospondyli*, and *Stereospondyli*), some of which show remarkable changes in size and differentiation during the remainder of the period, as well as adaptation to new surroundings. The entire evolutionary history of this phylum developed chiefly during the Pennsylvanian. Before the close of the period certain groups of the *Amphibia* had evolved into the *Protorosauria*, *Cotylosauria*, and *Theromorpha*, primitive orders of reptiles, the evolution occurring, according to Osborn, in a warm, terrestrial, semi-arid region. The significance of reptilian differentiation occurring before the lower Permian is shown in Williston's synoptic classification of the reptiles, which includes lower Permian representatives of five sub-orders of *Cotylosauria*, four sub-orders of *Theromorpha*, and representatives of the orders *Proganosauria* and *Protorosauria* (32).

It seems evident that so far as the vertebrate record is concerned the Pennsylvanian was a time in which some of the most important changes in the history of the vertebrate group either occurred or were foreshadowed.

Because of paleogeographic reasons, already mentioned, significant changes would not be expected in the sequence of Pennsylvanian invertebrate faunas, but an examination of the fossil record, though superficial, reveals important evolutionary changes. In marine life the corals, always a conspicuous group of supposedly warm-water affinity, show a marked decrease in number, a withdrawal equatorward, and a notable decline of the archaic, tetracoralla types. The physical geographic con-

ditions in eastern North America and western Europe seem to have been distinctly unfavorable to corals, as a group. The blastoids, giving indication early in the period of a recrudescence of their profusion in the Mississippian, abruptly decline at the top of the Brentwood limestone beneath the massive Winslow (Pottsville) conglomerate. The crinoids show a remarkable decrease, the dominant order, *Inadunata*, developing remarkable and exceptional structures, and they do not regain prominence until the Mesozoic. Cystoids and asteroids are almost unknown, and the echinoids with their sturdy skeletons characteristic of this ancient time are rare.

Bryozoans lose the important group with spiral support, and, like the brachiopods, diminish in number. Among the mollusks there is a decrease in the nautilids and a remarkable increase in complexity of suture among the ammonoids. Trilobites and eurypterids become almost extinct during the period. The pelecypod group become more modern in aspect. Among the non-marine forms the insects not only exhibit a remarkable development, but it is possible that holometabolism was introduced at this time. The spiders, land snails, and fresh-water gastropods and bivalves appear for the first time during this period. In fact, the invertebrate changes of the Pennsylvanian are of significance and importance, as might be expected from changes in the other branches of the organic world.

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DISCUSSION

FANNY CARTER EDSON, Tulsa, Oklahoma: Someone with a high professional standing and a scientific mind attacks a problem, puts as much time and thought on it as his other duties permit, forms some conclusions and publishes a paper on them. His attention may then be called to other problems and in the course of a long professional life many valuable ideas will be incorporated in his publications. We read the publications, and without giving any critical analysis to the facts, accept the published deductions as correct.

Giles has not done this. He has taken the ideas, generally accepted for the past half century, in regard to the "Pennsylvanian Climates and Paleontology," and given them some critical, constructive thought. He has taken the facts, one by one, and shown that other deductions can be drawn from them besides those set forth 50 years ago.

When we read the evidence for the old theory of "mild tropical, or almost tropical, humid conditions of world-wide extent" for the Pennsylvanian period, it seems almost incontrovertible. Giles has taken each of six lines of evidence for a warm, humid climate and shown that the reverse may be deduced —his presentation is so convincing that at the conclusion of his paper, the reader says to himself: "Perhaps the Pennsylvanian climates were not so warm and humid after all."

Scientific truth will eventually be achieved by more critical analysis and less willingness to accept other people's published ideas. I believe that Giles has made a distinct contribution to thought in regard to Pennsylvanian climates and paleontology.

SURFACE GEOLOGY OF COASTAL SOUTHEAST TEXAS[1]

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ABSTRACT

The formations at the surface in coastal southeast Texas are the "Lissie," Beaumont, Recent, and Recent terrace deposits. The Hockley scarp, one of the most striking physiographic features of the region, is a flexure scarp partly buried by alluvial deposits. The area in front of the Hockley scarp in southeast Texas is largely a deltaic plain composed of the coalescent deltas of late Pleistocene Trinity and Brazos rivers. The sands of the area of the Lake Charles loams and sands, currently mapped as Lissie, are continuous with the sands of the distributary ridges and are contemporaneous with the surface Beaumont clay, and that part of the Lissie at the surface seaward of the Hockley scarp is younger than that lying landward of the scarp and is a sandy phase of the Beaumont. An uplift of 20-30 feet is indicated in Orange County and in Cameron and Calcasieu parishes. A veneer of Recent sediments covers the seaward edge of the Beaumont clay. Two, possibly three, post-Pleistocene terraces are present in the valleys of the major streams. The soils of the early Recent terrace show the introduction of material from the Permian Red-beds.

INTRODUCTION

The formations exposed in coastal southeast Texas are: Lissie, Beaumont, Recent, and Recent terrace deposits.

The Lissie formation of the sandy prairie around Lissie in Wharton County was originally described by Deussen[3] as including the series of sands and gravels which underlie the Beaumont clay and overlie the Fleming clays. The outcrop of the Lissie was mapped by Deussen and is currently mapped as including essentially the broad belt of sandy soils lying between the area of outcrop of the Beaumont clay and the Fleming clay. The landward two-thirds of the belt of Lissie was mapped earlier by Kennedy[4] as the Lafayette gravel, and the coastward third lying in front of the Hockley Scarp was mapped as the Columbia sand.

The Beaumont formation of the area of Lake Charles clay soils around Beaumont, Jefferson County, Texas, was described by Ken-

[1]Manuscript received by the editor, May 10, 1930.

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[3](3) pp. 78-80. Numbers in parentheses indicate references at end of paper.

[4](1) pp. 12-31.

nedy[1] as including the clay series which forms the surface beds of that vicinity and which overlies a series predominantly composed of sands and gravels. The outcrop of the Beaumont formation is mapped at present as coincident with the broad belt of predominantly clay soils which parallels the coast at a distance ranging from 5 to 50 miles inland.

That part of Deussen's Lissie which lies south of the Hockley scarp and which corresponds with Kennedy's Columbia sands is indicated by the physiography and the distribution of the soils as belonging with the Beaumont formation, and the landward contact of the Beaumont formation is indicated as lying approximately at the foot of the Hockley scarp.

HOCKLEY SCARP

The Hockley scarp (Fig. 6) is one of the most striking physiographic features of coastal southeast Texas. It is a definite, somewhat composite seaward-facing scarp, which can be traced from south Texas, north of Eagle Lake, south of Sealy, past the Hockley salt dome and Tomball, south of Conroe, past Cleveland, Warren, and Kirbyville, and eastward into Louisiana. In southeast Texas, the Coastal Prairie at the foot of the scarp lies at a level of 160-175 feet, slopes south-southeastward at a rate of 3-5 feet per mile, and is a flat, almost featureless plain in the earliest stage of youth. The Lissie Prairie at the crest of the scarp lies at an elevation of 200-210 feet, rises landward at a rate of 9-15 feet per mile, and is in the early youth of a second cycle. In its southern part, the broad upland areas of the Lissie Prairie are an almost featureless but faintly rolling mature plain seemingly developed within a few feet of base-level. Along Brazos River and the main streams of San Jacinto River system, there has been a rejuvenation of erosion resulting in the cutting of youthful valleys into the mature plain. Landward, the mature relief of the topography becomes greater concurrently with the increasing slope of the general upland surface (Fig. 7). With the increasing relief, the effects of the rejuvenation become less evident and the early second-cycle youth grades into a robust first-cycle maturity.

No scarp comparable with the Hockley scarp lies between it and the present shore line, although a faint scarp is present at the 100-foot contour near Addicks in Harris County and near Kountze in Hardin County (Fig. 6), and a faint scarp is present between the 10 and 15-foot contours south of Hitchcock in Galveston County.

The Hockley scarp may be: (1) an ancient shore-line scarp marking the position of a shore line of the Pleistocene sea; (2) a flexure scarp

[1](1) pp. 27-29.

marking a deep-seated fault; (3) an uplifted flexure-shore-line scarp; or (4) a scarp of any one of the three preceding types partly buried under alluvial deposits.

The available evidence indicates that the Hockley scarp is a flexure scarp which has been buried to some extent by later alluvial deposits.

The main evidences for the presence of a flexure scarp are: (1) a northeast-southwest trend in Harris County east of Swanson, which controls the direction of considerable lengths of the scarp and which gives an abnormal direction to some of the drainage; (2) the presence of hills of considerable height in front of the scarp, particularly in the Tomball area; (3) the disappearing of a prominent stretch of the scarp into a narrow valley behind the hills near Tomball; and (4) the irregularities and offsets in the scarp.

Shore sands, bars, and spits, and similar shore-line phenomena are absent, but their absence would be explained by burial under the later deltaic alluvial deposits and such absence does not preclude the extension of a Pleistocene sea to the foot of the scarp. No positive evidence has been found in the area in favor of the extension of the sea to the scarp.

DELTAIC CHARACTER OF BEAUMONT CLAY AREA

The southern two-thirds of the Coastal Prairies area of southeast Texas is a deltaic plain composed of the coalescent deltas of ancient, probably late Pleistocene Trinity and Brazos rivers.

The evidence for the deltaic character of the coastward two-thirds of the Coastal Prairies in southeast Texas are the palmate series of sandy, topographic ridges spreading across Harris, Brazoria, Chambers, Jefferson, and Liberty counties. The predominant soil covering most of the southern half of Harris County, most of Brazoria County, except the Brazos bottoms and a zone along the coast (Fig. 1), and covering most of Jefferson County except the marshy zone contiguous to the coast, is the Lake Charles clay (Fig. 2). Sandy ridges, topographic ridges with sandy soils of the Lake Charles series and of the associated Calcasieu series, spread out across this area of the Lake Charles clay and in their form and pattern delineate a characteristic deltaic distributary system, as can be seen from Figures 1-5. The Lake Charles very fine sandy loam is found only on the crests of the ridges. The Lake Charles clay loam, which is a slightly less sandy soil, borders it on the flanks of the ridges or may cover both the crest and upper flanks of the ridges. The ancient stream channel is well preserved both on Blue Ridge in Brazoria and Fort Bend

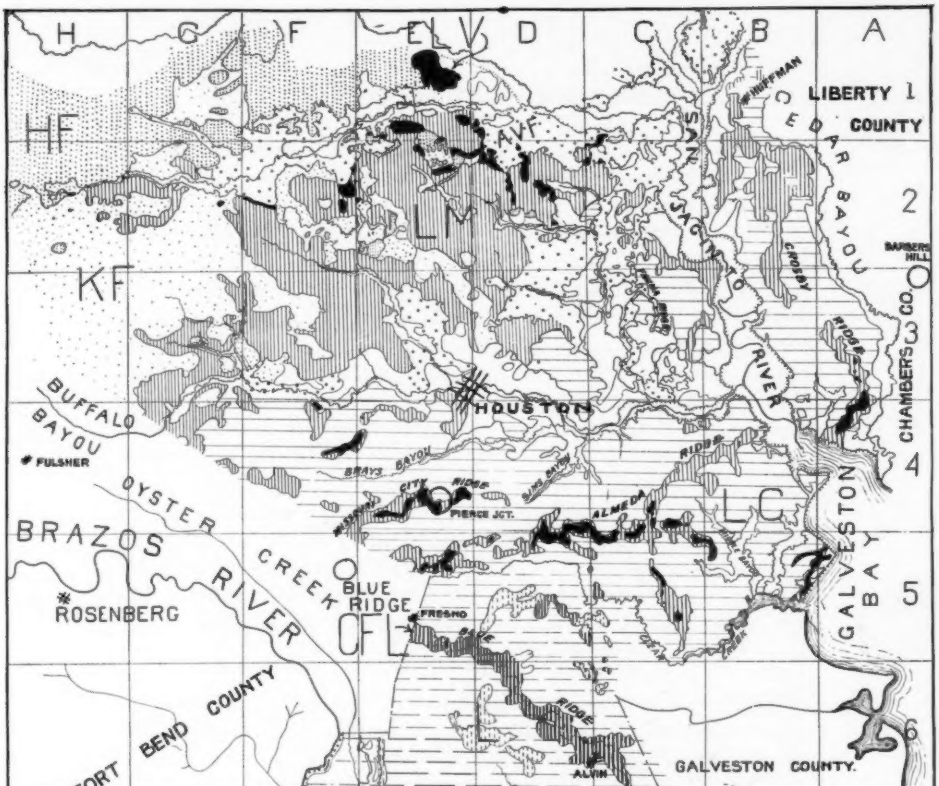

FIG. 1.—Soil map of Harris County and of parts of Brazoria County, Texas (after U. S. Bureau of Soils).

H. F.	= Hockley fine sandy loam	L.	= Lake Charles fine sandy loam
K. F.	= Katy fine sandy loam	A. V. F.	= Acadia fine sandy loam
L. V.	= Lake Charles very fine sandy loam	H. C.	= Houston black clay
L. M.	= Lake Charles clay loam	Y. S. L.	= Yazoo fine sandy loam
L. C.	= Lake Charles clay	S. C.	= Sharkey clay
C. F. L.	= Calcasieu fine sandy loam	G. C.	= Galveston clay

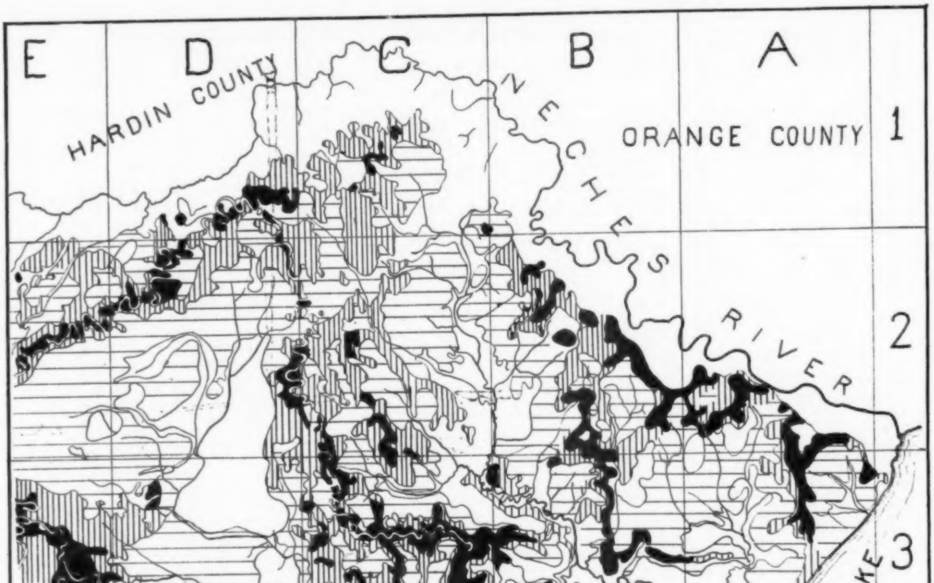

FIG. 2.—Soil map of Jefferson County, Texas, showing the distributaries of an ancient Trinity River (after U. S. Bureau of Soils).

L. I. = Lake Charles very fine sandy loam
L. S. = Lake Charles silt-clay loam
L. C. = Lake Charles clay
L. O. = Lomalto clay

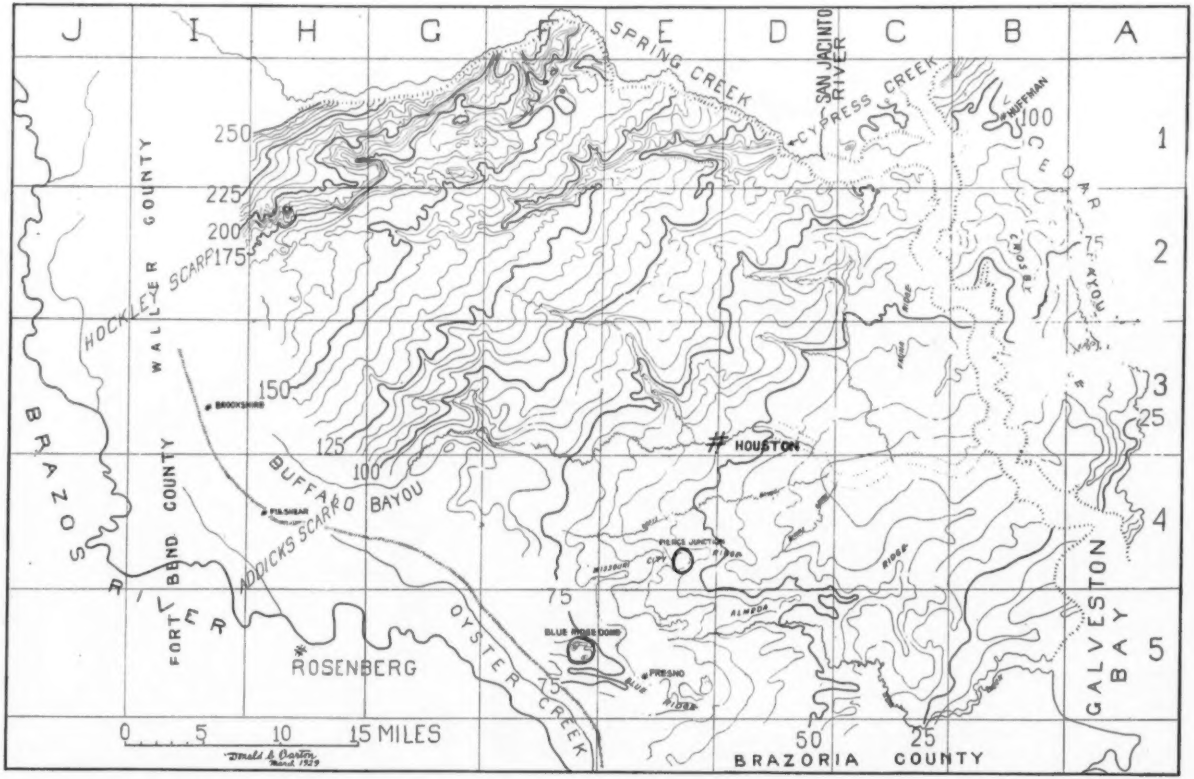

FIG. 3.—Topographic map of Harris County and small parts of Fort Bend and Brazoria counties. (Topographic map of Harris County after U. S. Geological Survey, but with recent gullying omitted; topography in Fort Bend and Brazoria counties from several commercial surveys.) Contour interval, 5 feet.

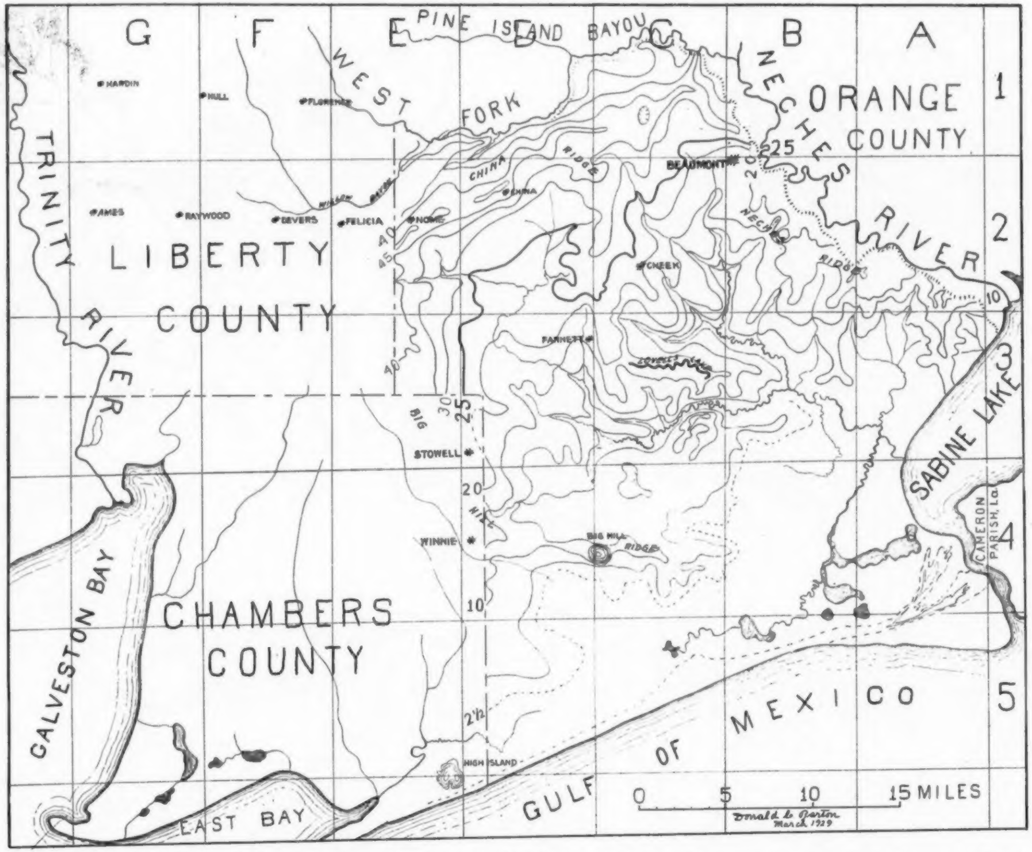

FIG. 4.—Topographic map of Jefferson County, Texas. Contour interval, 5 feet. (Topography after U. S. Bureau of Soils.)

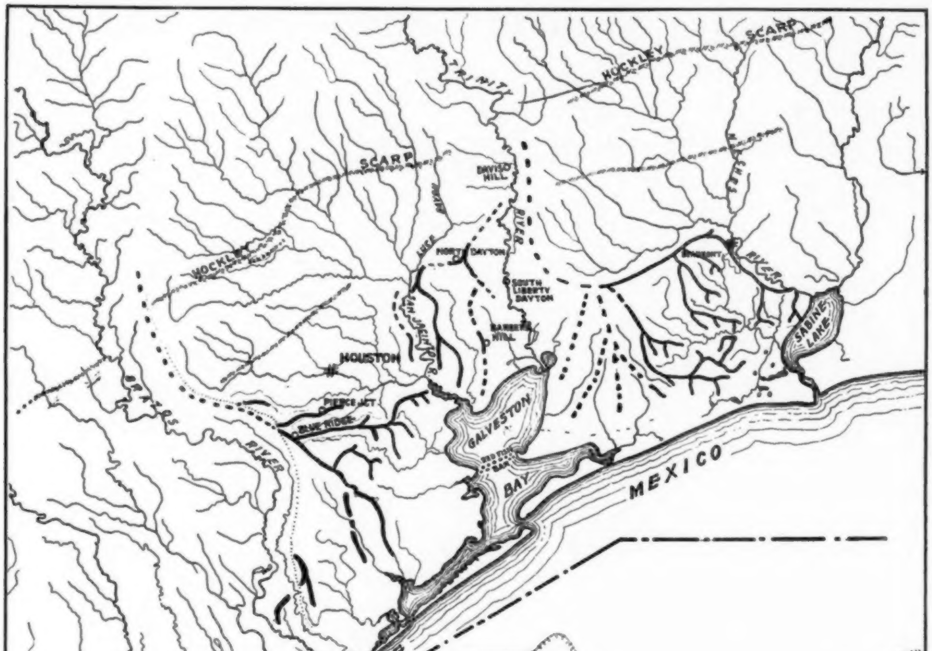

FIG. 5.—Sketch map of southeast coastal Texas.

counties and on parts of the China and Big Hill ridges of Jefferson County (Fig. 5).

The ancient stream channel of the China Ridge can be followed into Lovell's Lake (Fig. 4, *C*-3), a long meandering lake above the general level of the surrounding prairie.

The Lake Charles clay (soil) is the soil developed on the Beaumont clay (geological formation). The subsoil of that soil and of the Lake Charles clay loam are characterized by the same calcareous nodules which characterize the Beaumont clay. The area of predominantly Lake Charles clay soils coincides very closely with the area currently mapped by geologists as Beaumont clay.

The source sediments of the Lake Charles clay loam and fine sand loam of the distributary ridges seemingly must be contemporaneous with the source sediments of the Lake Charles clay in the broad inter-delta and inter-distributary basins. The normal order of deposition from a distributary stream is: sand on the crest of the natural levee close to the stream channel, sandy clays on the flanks, and clays in the back bottoms away from the stream. That is the distribution of the Lake Charles fine sandy loam, clay loam, and clay on the distributary ridges and the inter-ridge basins. Those soils grade from the fine sandy loam on the crest of the ridge into the clay loam and from the clay loam into the clay in the basin area, and all have certain family characteristics in common.

The conclusion seems justified that the source sediments of the sandy soils of the distributary ridges and the source sediments of the clay soils of the inter-distributary basins are contemporaneous and assignable to the same geologic formation.

RELATION OF SOILS OF COLUMBIA SAND AREA TO SOILS OF DELTAIC PLAIN OF BEAUMONT AREA

The area of Deussen's Lissie south of the Hockley scarp and of Kennedy's Columbia sands in Harris County is covered by sandy soils of the Lake Charles, Katy, and Acadia series in approximately the following proportions.

	Per Cent
Lake Charles very fine sandy loam	2
Lake Charles clay loam	43
Katy fine sandy loam	30
Acadia fine sandy loam	15
Hockley fine sandy loam	5
Others	5

The Edna very fine sandy loam is neglected, as it has been developed

in small spots widely and irregularly separated in the area of all the sandy soils.

The Acadia series of soils mainly lies adjacent to the streams, and to a considerable extent covers what may be an indistinct terrace only slightly below the average prairie level. The Acadia soils seem probably to be derived from deposits very slightly younger than the parent material of the predominant Lake Charles soils.

The Lake Charles loams of this belt are continuous with the similar loams forming the sandy crests of the distributary ridges in the area of the Lake Charles clays and are in about the same stage of evolution of the soil profile. Soils are not wholly reliable geologic criteria, but in the present study, it seems reasonable to make the following assumptions.

1. Some difference in character should be present between the source material of the Lake Charles loams of this belt and the source material of the Lake Charles loams and clay of the broad area of Lake Charles clay at the south, if those source materials belong to different formations.

2. If the former is Lissie and the latter is Beaumont, the soil-forming forces should have been acting for different lengths of time in the two areas.

3. Therefore, if the former is Lissie and the latter is Beaumont, the soils developed should show some distinct differences, either in soil type or in development of the soil profile.

4. The absence of those distinct differences between the Lake Charles loams of this belt and the Lake Charles loams of the distributary ridges extending across the broad area of the Lake Charles clay strongly indicates the contemporaneity of the source sediments of both.

The Lake Charles loams of Deussen's Lissie-Kennedy's Columbia sand area lie between elevations of 60-85 feet and 125 feet above sea-level and in an area with a slope of about 5 feet per mile immediately in front of the Hockley scarp, back of which the general slope of the surface is greater. The Lake Charles clay lies below an elevation of 80-60 feet and in an area with slopes generally of 2½ feet per mile.

The distribution of the Lake Charles soils, therefore, is in an entirely normal order of contemporaneous deposition: sandier sediments over the inner belt of greater slope; clay soils over the outer belt of lower and flatter slopes; and narrow strips of the sandier soil bordering the channels of ancient streams extending across the lower and flatter area; channels along which the higher velocities of flow, of course, persisted out across the area of relatively stagnant water.

The Katy fine sandy loam lies in the western part of the belt of Deussen's Lissie-Kennedy's Columbia sands in Harris County south of the Hockley scarp. The Katy fine sandy loam is intermediate between the Lake Charles soils and the Hockley soils, which in Harris County are the predominant soils back of the Hockley scarp. It has been formed from material similar to, but slightly more sandy than, the Lake Charles soils; in its formation, the leaching of the calcium carbonate has gone to a much greater depth and seems to have been going on for a much longer period of time than in the Lake Charles soils. Where the Katy fine sandy loam extends down into the area of predominantly Lake Charles loam, the former tends to be on the crest of rather vague, broad plunging ridges.

The Katy fine sandy loam has many characteristics in common with the Hockley fine sandy loam and seems to have developed from the same type of material.

The area in Harris County north of the Hockley scarp is characterized by a strong predominance of the Hockley fine sandy loam. That soil and the Katy fine sandy loam are closely associated in character, but the contact between the area of predominantly Hockley soils and the area of predominantly Katy soils gives a fairly close delineation of the position of the Hockley scarp.

The postulation of a younger age for the source sediments of the Katy soils than for the source sediments of the Hockley soils seems justified. Although unaware of the Hockley scarp, the United States Bureau of Soils has mapped the soils north of it predominantly as Hockley soils and has mapped the area lying south of it predominantly as Katy soils. As the soil-forming conditions are almost the same in the two areas, a slight difference seems indicated between the respective source materials of the two soils. The plain back of the Hockley scarp is in early maturity; the plain in front of the scarp is in very early youth. If the erosion producing that maturity largely antedated the formation of the Hockley scarp, there must have been subsequent deposition to form the youthful plain. If that erosion in considerable part post-dated the formation of the Hockley scarp and if the Hockley scarp is a flexure scarp, the steeper slopes of the scarp and of the plain north of it compared with the very low slope of the plain south of it and the weakness of the forces of erosion over the latter plain should lead to the formation of outwash fans spreading out from the foot of the scarp across the plain in front. The source sediments of the Katy soils in either situation would be younger than the source sediments of the Hockley soils. The plain of the Katy soils

and the Hockley scarp show no indication of a marine origin, but if they did have a marine origin, the source sediments of the Katy soils necessarily would be younger than those of the Hockley soils.

The relation between the respective source sediments of the Katy soils and of the Lake Charles soils is not entirely clear. The tentative hypothesis which appeals to the writer as plausible is: (1) that the latter sediments are primarily material deposited by the waters of through streams and are composed of the re-worked material from all parts of the upstream drainage basin of those streams, and (2) that the former sediments are primarily re-worked "Lissie," eroded from the area immediately behind the Hockley scarp, mixed to some extent with the material brought down by the through streams, and deposited as a flat outwash in front of the scarp.

The evidence for this hypothesis is: (1) the relative distribution of the two soils, the Katy soils immediately in front of the Hockley scarp and the Lake Charles soils in the extensive deltaic plain; (2) the seeming younger age of the source sediments of both soils compared with those of the Hockley soils; and (3) the fact, according to the Bureau of Soils, that the Katy soils are intermediate between the Lake Charles and the Hockley soils and derived from material similar to both the respective source materials of the latter two soils. There is, however, a possibility that the source materials of the Katy soil belong to a flat outwash plain younger than the Hockley scarp, and older than, but not buried by, the deltaic deposition in which the source materials of the Lake Charles soils were laid down.

"COLUMBIA SANDS"—SANDY PHASE OF BEAUMONT

The sandy sediments which have caused the zone of sandy soils between the Hockley scarp and the landward edge of the broad zone of Lake Charles clay soils, in large part at least, are the equivalents of the Beaumont clay. The Beaumont should be designated the Beaumont formation, a predominantly clayey formation but with this sandy phase at its landward edge.

The sandy phase of the Beaumont formation may have little thickness and may be only a veneer over the underlying sandy-gravelly series; some of the hills of the area between Tomball and Cypress Creek are suspected by the writer to be hills which have never been covered by the Beaumont sediments. Wolfs Hill may be another such hill. As the sandy phase of the Beaumont formation is somewhat similar to the underlying sandy-gravelly series and as both are non-fossiliferous and as the first

few hundred feet in wells is logged very carelessly, the data now available presumably are not sufficient to distinguish between the two formations from well data. The time interval between the deposition of the Beaumont formation and that of the sandy series of the zone immediately back of the Hockley scarp was perhaps infinitesimally short, but the surface beds south of the Hockley scarp are slightly younger than those north of the scarp.

The town of Lissie, the type locality for the Lissie formation, seems to lie south of the Hockley, but is in an area for which good topographic and soil maps are not available. The name, Lissie, may prove to be synonymous with, and younger than, Beaumont, as the name for the surface formation, and may have to be dropped.

MARINE SEAWARD EDGE OF BEAUMONT

The seaward edge of the Beaumont formation at the surface is marine or brackish-water, although in general the Beaumont beds at the surface are deltaic sediments laid down above sea-level.

An uplift of 20-30 feet is indicated by physiographic evidence in Orange County, Texas, and Cameron and Calcasieu parishes, Louisiana, and from Colorado River southwest along the coast. The evidence for the uplift is: (1) an extensive net of meandering and intercommunicating marshy swales and wet-weather drainage ways are shown by the topographic map of Orange County and seemingly represent the almost obliterated traces of the marsh drainage system similar to that of Terrebonne Parish to-day; (2) the practical absence of organized drainage, except for a few extended streams, over the vast, almost featureless Cameron marshes seems to indicate that the so-called land there is only moderately recently uplifted sea-bottom; (3) oyster-shell reefs are found in the prairie east of Lake Charles at an elevation of 15-20[1] feet above sea-level; and (4) a well developed uplifted and abandoned barrier is present in the Corpus Christi area and is shown by the Soil Survey maps as extending northeast as far as the southwest shore of Matagorda Bay. In coastal southeast Texas, east of the Brazos, there is no evidence of the continuation of that shore line or the presence of uplifted shell reefs. Their absence, however, is in keeping with the conditions of active delta building which must have prevailed in the area. The uplift must have antedated the cessation of active delta building by the ancient Brazos and Trinity rivers, for the weak deltaic sediments should have yielded

[1]Estimated.

rapidly to wave attack as soon as the delta ceased to grow actively, but no trace can be recognized of the shore line formed by such erosion.[1]

RECENT DEPOSITS

Non-terrace deposits of Recent age are found only in a veneer of sands and clays lying on the Beaumont clays near the coast. The "Recent" sediments comprise (1) a sandy barrier beach and (2) a series of clays and silty clays veneering the Beaumont clay.

The barrier beach is low and insignificant compared with the barrier beach on the Atlantic coast of the southeastern states, as it rises only to an elevation of 5-7 feet above mean tide level. It is, in general, a somewhat simple ridge compared with the fairly common multiple character of the Atlantic barrier beach with its abandoned back ridges. A series of abandoned beach ridges can be recognized in the southeast corner of Jefferson County and across Sabine Pass in the southwest corner of Cameron Parish. These abandoned beach ridges, on the Louisiana side at least, are of approximately the same character and elevation as the modern beach ridge and indicate stability of sea-level for a considerable period of time back into the recent geological past.

Although insignificant compared with the Atlantic beaches, the barrier is one of the most pronounced features of this area. No topographic scarp comparable with its front exists back of it in southeast Texas until the Hockley scarp is reached (Fig. 6). Sabine Bank and other banks on the same line, however, form a more pronounced ridge offshore. In the Corpus Christi area, an elevated barrier beach ridge lies back of it on the edge of the mainland. A broad east-west topographic ridge with an elevation of about 25 feet has profoundly affected the drainage pattern of Calcasieu Parish and has incited speculation in the writer's mind as to whether it is an easterly equivalent of the elevated Corpus Christi beach ridge, or whether it is a structural ridge.

The Recent clays and silts are reflected in the soils, although not in the topography. The prairie extends, without topographic or physiographic break, from the area of the Beaumont clay into the area of the Recent clays, but within the area of the Recent clays, the prairie gradually becomes increasingly marshy. The soil is mapped by the Bureau of Soils as the Harris (Galveston, Lomalto) clay, which is a quite different soil from the Lake Charles clay. The slightly brackish-water and marshy conditions under which this soil has formed must, in part, however,

[1]The advance sheet just received of Hitchcock Quadrangle, Galveston County, shows a scarp between 10 and 15 feet elevation above sea-level. This scarp may represent such a shore line.

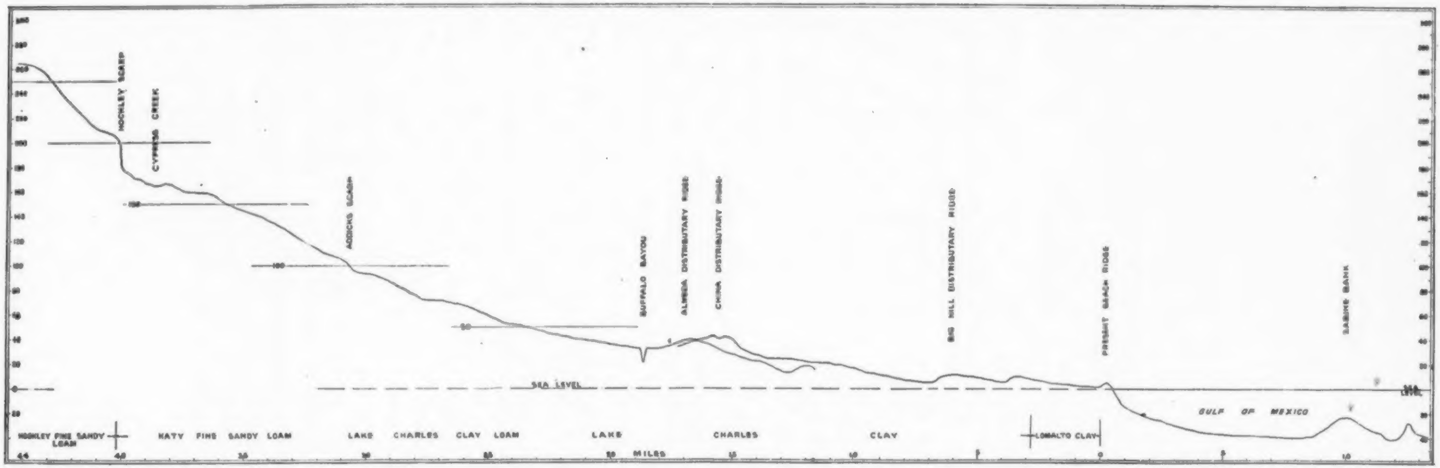

FIG. 6.—Topographic profile across coastal southeast Texas. Upper (left) profile is across Harris County and is taken from the U. S. Geological Survey topographic sheets; (right) profile is across Jefferson County and adjacent part of the gulf and is taken from the U. S. Bureau of Soils report on Jefferson County and from the U. S. Coast and Geodetic Survey coast charts.

account for its difference from the Lake Charles clay. As the Recent sediments lie at an elevation of less than 10 feet above sea-level, they are subject to occasional inundations and a rare and slight accretion of sediments. The recent sediments of Jefferson County in considerable part seem to be due to the silting up of the lagoon back of the barrier beach; the topographic profile perpendicular to the coast in Jefferson County shows a marked flattening over the area of Recent sediments. There is no reason to expect any break between the Beaumont clays and the Recent clays.

TERRACE DEPOSITS

Two, possibly three, distinct sets of terrace deposits are present: a late Recent series, an early Recent series, and possibly a late Beaumont series characterized by the Acadia soils.

The Acadia soils are closely associated with the Lake Charles soils, but show a strong tendency to occur in what would seem to have been depressions in the plain of the Lake Charles soils. Although they are not uncommon in the middle of inter-stream areas, and although in places their occurrence is without relation to drainage systems, the Acadia soils more characteristically lie in belts bordering Buffalo Bayou and its tributaries, San Jacinto River and its tributaries, Cedar Bayou, and Pine Island Bayou. Characteristically, they are not found within the valleys of those streams, but on the adjacent edge of the upland. In general, they can not be recognized as covering a distinct terrace, but as covering vague broad depressions, which antedate the erosion cycle. The broad, vague basin lying east of Houston in Harris County (Fig. 3, *DC* 34), extending as an indistinct rising trough toward Humble and north of Buffalo Bayou, for example, is characterized by the Acadia soils rather than the Lake Charles soils. The Acadia soils, on the whole, are better drained than the Lake Charles soils and have attained a more advanced stage of development. Whether this slight difference in the soil-forming conditions could have produced Acadia soils from the parent material of the Lake Charles soils, the writer does not know.

The early Recent terrace deposits are associated with a set of terraces which lie about midway between the general level of the lowest bottom lands and the normal level of the Coastal Prairies of the area of the Beaumont formation. Although small remnants of terraces may be found along San Jacinto River at almost any level between that of the Coastal Prairie and that of the present lowest bottom lands, most of those remnants, particularly the larger, lie within 3 feet of a surface (Fig. 7) which diverges from that of the present lowest bottom lands a few miles

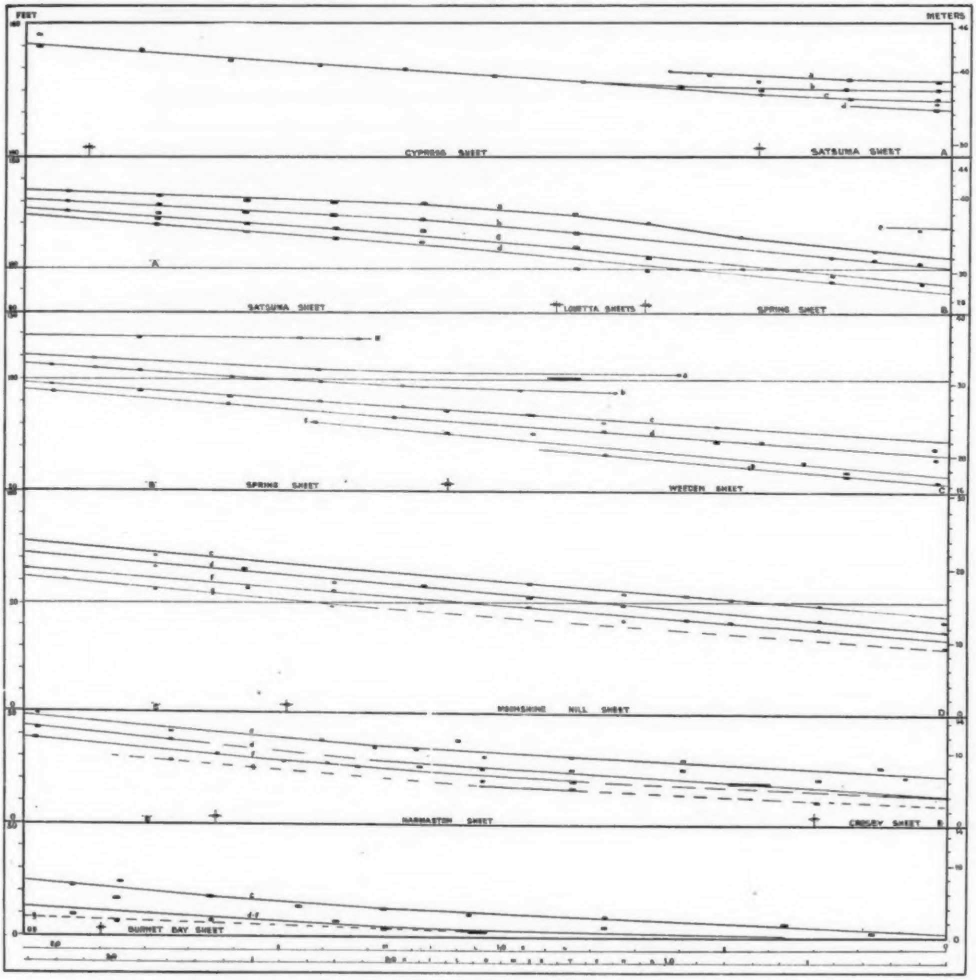

FIG. 7.—Longitudinal topographic profiles along San Jacinto River-Cypress Creek showing the terraces indicated on the U. S. Geological Survey topographic sheets.

north of the confluence of San Jacinto River with Buffalo Bayou and rises to an elevation above sea-level of about 50 feet north of Humble; the normal elevation of the Coastal Prairies at that point would be about 100 feet, and the elevation above sea-level of the lowest bottom-land level is about 20 feet. This set of terraces is characterized by soils of the Kalmia series,—the Kalmia sand and the Kalmia fine sandy loam. The Kalmia soils are grayish and are without the calcareous concretions which characterize the subsoil of the Lake Charles soils, or the calcareous and the ferruginous concretions which characterize the Acadia. The Kalmia soils resemble the Ochlockonee soils, which characterize the lowest bottom lands. Usable topographic maps are not available for the corresponding reaches of Brazos, Trinity, Neches, and Sabine rivers. Road reconnaissance across the Brazos Valley at various places south of the Hockley scarp seems to show a set of terraces corresponding approximately with the early Recent set of terraces of San Jacinto River. On the Columbia-Angleton road, it can not be distinguished, but a broad set of terraces at approximately a common level are well developed in the vicinity of the DeWalt salt dome, Sugarland, and northward. This terrace level is well below the general level of the Coastal Prairies and is well above the general level of the lowest bottoms. The decadent Oyster Creek flows on this terrace on the east side of the valley.

Oyster Creek and the terrace have some mutual relation which as yet is not entirely clear. The terrace has been re-worked considerably by the creek. The soils of the terrace predominantly have a dark chocolate color. The Yazoo soils of Brazoria County on the south and the Miller soils of Washington County on the north probably in part correspond with the soils of this terrace.

The Miller soils are developed on the flood plains of streams bringing down sediments from the area of outcrop of the Permian Red-beds.

The contrast between the predominantly chocolate soils and sediments of this terrace and the black, gray, and brown soils of the Lake Charles, Acadia, Katy, and Hockley soils and the underlying light gray to light yellow or light brown sediments incites speculation.

Shortly after the beginning of the erosion era in the Coastal Prairies area, the ancient Brazos River ceased to bring down the light-colored, gray to brown sediments, which weather to dark gray, black, or dark brown soils, and began to bring down chocolate-colored sediments strongly colored by material probably derived from the Permian Red-beds. This change seemingly must mark some geologic happening in the in-

terior and suggests a possible clue to the time correlation of Recent geologic history in the Coastal Prairie area with that of the interior.

The chocolate to dark reddish brown color of sediments derived from the Permian Red-beds suggests also a possible paleogeographic clue, which might repay investigation. The Plio-Miocene is largely re-worked Cretaceous material and as such should be drab-colored. Unweathered chocolate to dark reddish brown gumbo beds, however, are encountered in the Plio-Miocene, although in very subordinate amount in comparison with the drab and blue gumbo. It might be possible to identify these chocolate to dark reddish gumbos as re-worked Permian Red-bed material and it might then be possible to deduce interesting information about the paleogeography and paleogeölogy of Plio-Miocene Texas and southern Oklahoma.

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10. Topographic maps.
    (1) Harris County
        U. S. Geol. Survey topographic sheets
    (2) Orange County
        U. S. Geol. Survey topographic sheets
    (3) Jefferson County
        A reconnaissance topographic map is given in an early edition of Ref. 7.

(4) Southwest of Brazos River

For many quadrangles very generalized topographic sheets are available in a series published by the Corps of Engineers, U. S. A.

(5) Offshore

U. S. Coast and Geodetic Survey Coast Pilot Charts 1116-17, 1279-83.

(6) Galveston County

Advance sheets are available for a few quadrangles of the U. S. Geol. Survey topographic map.

KREYENHAGEN SHALE AT TYPE LOCALITY, FRESNO COUNTY, CALIFORNIA[1]

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ABSTRACT

The Kreyenhagen shale at the type locality overlies with seeming conformity the Domengine (upper middle Eocene) sandstone and is overlain unconformably by beds of Temblor (lower middle Miocene) age. The Kreyenhagen is composed of shale of the kind generally characterized as an "organic shale," with a few lenses of fine-grained sandstone and limestone. Only one mollusk, *Pecten interradiatus*, was found in the shale. *Foraminifera* are ordinarily scarce and poorly preserved; and only a scanty fauna was obtained from the base of the formation. *Radiolaria* are plentiful throughout; diatoms, however, were not noticed.

The evidence at hand points to a deep marine basin as the place of deposition which was possibly within the bathybic zone, but in any event exceeded a depth of 50 fathoms. The temperature at the bottom was cool, although the climate on the land may have been tropical. The complexion of the foraminiferal fauna is more Eocenic than Miocenic. The stratigraphic position of the Kreyenhagen between Domengine (middle Eocene) and Temblor (middle Miocene) proves that it is upper Eocene, Oligocene, or lower Miocene in age. Paleontologic evidence as well as the unconformity between the Kreyenhagen and the Temblor suggests an Eocene or Oligocene rather than a Miocene age for the Kreyenhagen shale.

INTRODUCTION

The term Kreyenhagen shale was first proposed by F. M. Anderson[3] for a lithologic unit which rests on Eocene sandstone and which is overlain by Miocene sandstone. The type locality is on Canoas Creek (Fig. 1 and Fig. 2), about 20 miles south of Coalinga, Fresno County, California, latitude 35° 58′ N., longitude 120° 16′ W. of Greenwich (Sec. 32, R. 16 E., T. 22 S., Mount Diablo base and meridian).

F. M. Anderson believed that the Kreyenhagen shale was of Eocene age. He correlated the type Kreyenhagen with a similar shale at the north which Ralph Arnold and Robert Anderson[4] proved to be partly

[1]Read before the Pacific Coast Section of the Association at San Francisco, November 22, 1929. Manuscript received by the editor, April 19, 1930. Published by permission of G. C. Gester, chief geologist, Standard Oil Company of California.

[2]Bin XX, Geological department, Standard Oil Company of California. Introduced by W. S. W. Kew.

[3]F. M. Anderson, "A Stratigraphic Study in the Mount Diablo Range of California," *Proc. California Acad. Sci.*, Vol. 2 (1905), p. 163.

[4]R. Arnold and R. Anderson, "Geology and Oil Resources of the Coalinga District, California," *U. S. Geol. Survey Bull. 398* (1910), pp. 58-59, 67-70.

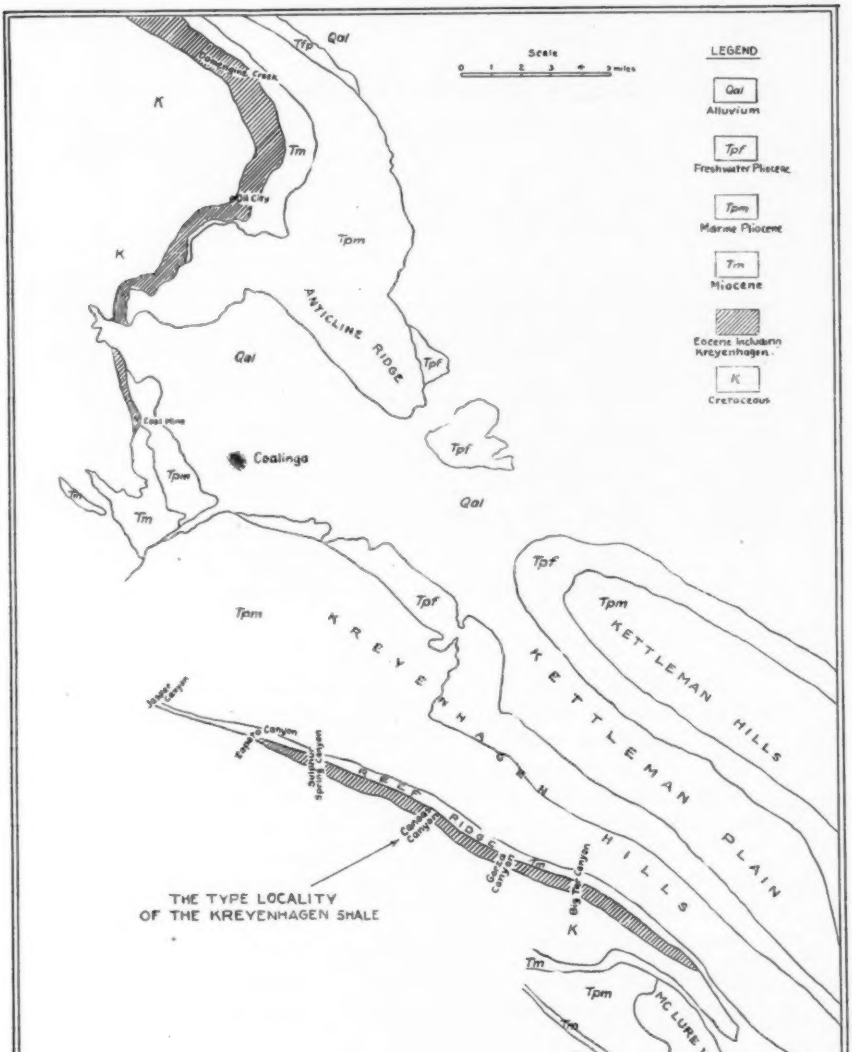

FIG. 1.—Index map of type locality of Kreyenhagen shale.

FIG. 2.—Canoas Creek. Temblor (Miocene) reef beds forming Reef Ridge in foreground and Eocene sandstone in distance with Kreyenhagen shale between, the latter showing low relief. Looking southwest.

Cretaceous. They referred to the Kreyenhagen shale as the upper Tejon (upper Eocene) member, overlying the Tejon sandstone with apparent conformity and separated from the Miocene above by a disconformity. The so-called Tejon was mapped as a narrow belt becoming thinner toward the northwest and disappearing toward the southeast and the northwest under the overlapping shales of the Miocene.

The name Kreyenhagen was again applied by Robert Anderson and R. W. Pack[1] to a diatomaceous shale north of Coalinga because of similar stratigraphic position between the so-called Tejon (upper Eocene) and the so-called Vaqueros (lower Miocene) sandstone. More recently G. D. Hanna[2] correlated the Kreyenhagen south of Coalinga with the middle Eocene north of Coalinga. Bruce L. Clark[3] gave little attention

[1]R. Anderson and R. W. Pack, "Geology and Oil Resources of the West Border of the San Joaquin Valley North of Coalinga, California," *U. S. Geol. Survey Bull. 603* (1915), p. 50.

[2]G. D. Hanna, "The Age and Correlation of the Kreyenhagen Shale in California," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 6 (September, 1925), pp. 990-99.

[3]Bruce L. Clark, "The San Lorenzo Series of Middle California," *Univ. California Pub., Bull. Dept. Geol.*, Vol. 11 (1918), p. 63.

to the type Kreyenhagen, but endeavored to show that its seeming equivalent, the diatomaceous shale north of Coalinga, is Oligocene in age, as was first suggested by R. Anderson and R. W. Pack. Clark[1] furthermore believed that the so-called Tejon north of Coalinga was intermediate between upper and middle Eocene; he therefore established a new Eocene horizon, for which he revived F. M. Anderson's name Domengine sandstone.

The only fossil listed in the literature from the Kreyenhagen of the type locality is *Pecten interradiatus* Gabb, mentioned by G. D. Hanna.[2] He incorrectly inferred that "*Orbitolites* sp. a," listed by R. Arnold and R. Anderson[3] from the Eocene sandstone, came from the Kreyenhagen shale. The so-called Kreyenhagen *Foraminifera*, referred to by F. M. Anderson,[4] and J. A. Cushman and G. D. Hanna,[5] were obtained from the Cretaceous and the middle Eocene rocks, respectively, north of Coalinga.

In this paper are described the Kreyenhagen shale at its type area on Reef Ridge and its relations to the adjacent formations. Special attention has been given to microscopic fossils and lithology.

Fossils were collected at the following localities.

A. Mollusca

Locality 1.—Fresno County, California. Cholame Quadrangle. SE. ¼, Sec. 32, T. 22 S., R. 16 E. In the narrow part of Canoas Canyon. Domengine sandstone.

Locality 2.—Kings County, California. Cholame Quadrangle. NE. ¼, Sec. 20, T. 23 S., R. 17 E. In canyon 1 mile south of Big Tar Canyon. Domengine sandstone.

Locality 3.—Kings County, California. Cholame Quadrangle. Sec. 27, T. 23 S., R. 17 E. On the southwest flank of Reef Ridge, north of McLure Valley. Domengine sandstone. (U. S. G. S. Locality 4617.)

B. Foraminifera

Locality I.—Fresno County, California. Cholame Quadrangle. SW. ¼, Sec. 32, T. 22 S., R. 16 E. On divide ½ mile

[1] B. L. Clark, "The Domengine Horizon Middle Eocene of California," *Univ. California Pub., Bull. Dept. Geol.*, Vol. 16 (1926), pp. 99-118.

[2] *Op. cit.*, p. 996.

[3] *Op. cit.*, pp. 70-71.

[4] *Op. cit.*, p. 192.

[5] J. A. Cushman and G. D. Hanna, "Foraminifera from the Eocene near Coalinga, California," *Proc. California Acad. Sci.*, Vol. 16 (1927), pp. 205-29.

northwest of Canoas Creek. Kreyenhagen shale. (L. S. J. U. Locality 320.)

Localities II-IV.—Kings County, California. Cholame Quadrangle. SE. ¼, Sec. 17, T. 23 S., R. 17 E. In canyon 1 mile south of Big Tar Canyon. Sandy zone at base of Kreyenhagen shale. (L. S. J. U. Locality 321.)

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SUBJACENT FORMATION

DOMENGINE (UPPER MIDDLE EOCENE)

The Eocene sandstone, which underlies the Kreyenhagen shale with seeming conformity and overlies the formation mapped as Cretaceous unconformably, has a maximum thickness of 500 feet in the region of Big Tar Canyon. This sandstone, ordinarily cemented with calcite, varies from conglomeratic to fine-grained, and is poorly bedded or massive. In addition to angular grains of quartz and comparatively fresh feldspar, altered ferromagnesian minerals, mica, and chert may be seen in thin sections. Lenses carrying marine mollusks with tropical affinities are common. Lithology and fauna thus suggest deposition in a shallow, tropical sea.

The sandstone is correlated with the Domengine (upper middle Eocene) horizon north of Coalinga on paleontologic evidence (Fig. 3).

KREYENHAGEN SHALE

The Kreyenhagen shale at its type area forms a belt, about 15 miles long, disappearing toward the southeast under the overlapping Santa Margarita (?) (upper Miocene) shales, and decreasing in thickness toward the northwest; it was not found west of Sulphur Spring Canyon of Zapato Creek, probably because of an overlap of the Temblor sand-

GENERALIZED COLUMNAR SECTION OF THE KREYENHAGEN ON REEF RIDGE

Age		Thickness in feet	Symbol	Lithology	Fossils*
Miocene	Temblor	00–100		Fine- to coarse-grained, gray to brown sandstone, interbedded with sandy shale. Conglomerate of siliceous pebbles at the base.	
				Unconformity	
Kreyenhagen		0–100		Brown clay shale interbedded with opaline shale.	
		100–300		Rather soft, brownish to black, thinly bedded siliceous, argillaceous and calcareous shales, weathering white. Impregnated with oil. Gray limestone nodules, black on a fresh surface, 1-2 feet in diameter, are frequent. Gypsum and jarosite occur abundantly in fractures.	Radiolaria common throughout the shale.
		400		Purplish brown clay shale.	Radiolaria abundant.
		500–600		Oil impregnated, platy, calcareous shale.	Fish scales, Pecten interradiatus.
		600–700		Brittle, yellow weathering, platy calcareous shale, interbedded with purplish brown, soft and brittle argillaceous shale, and fine-grained gray sandstone.	Foraminifera I.
		700–800		Lense of hard gray limestone weathering yellowish.	
		800		White massive friable sandstone grading into sandy shale.	
		800–900		Yellow weathering, platy, calcareous shale interbedded with gray sandy shale.	Pecten interradiatus. Foraminifera II. Foraminifera III.
		1000		Gray massive sandy shale.	Foraminifera IV.
				Unconformity?	
Eocene	Domengine	1100		Friable gray sandstone.	
		1200–1300		Massively bedded, concretionary, oil impregnated sandstone.	
		1400		Fossiliferous hard sandstone.	Mollusca 1, 2, 3. Discocyclina clarki

* Locality numbers on preceding page correspond with those in this column.

FIG. 3

FOSSILS AS INDICATED IN COLUMNAR SECTION, FIG. 3

A. Mollusca	Locality 1	2	3
Amaurellina clarki Stewart	..	x	..
Cardium brewerii Gabb	..	x	..
Conus n. sp.	..	..	x
Conus sp. indet.	x	..	..
Ficopsis remondii Gabb	..	?	..
Galeodea tuberculiformis Hanna	..	..	x
Globularia hannibali Dickerson	..	x	x
Glycimeris sp.	..	..	x
Solen sp. indet.	x	x	..
Turritella andersoni Dickerson	..	?	x
Turritella buwaldana Dickerson	x	x	x
Turritella uvasana Conrad	x	x	x
Venericardia ionensis Waring	..	x	..

B. Foraminifera	I	II	III	IV
Asterigerina (?)	x	..	..	..
Bulimina cf. *inflata*	..	..	..	x
Cibicides sp. A	..	..	..	x
Cibicides sp. B	x	..	..	..
Cibicides sp. C	..	..	..	x
Cibicides sp. D	..	..	..	x
Clavulina	..	..	..	x
Dentalina	..	x	..	..
Ellipsonodosaria (?)	..	..	..	x
Epistomina (?)	..	x	..	..
Eponides	..	..	x	..
Glandulina laevigata ovata	..	..	x	x
Globigerina	x	x	x	x
Gyroidina	..	x	x	x
Lagenonodosaria (?)	..	..	..	x
Lenticulina	..	..	..	x
Nodosaria sp. A	x	..	..	..
Nodosaria sp. B	..	x	..	..
Nodosaria sp. C	..	..	..	x
Plectofrondicularia	x	..	x	..
Pleurostomella (?)	..	..	..	x
Robulus sp. A	..	..	..	x
Robulus sp. B	..	x	..	x
Rotalia	x	..	..	..
Spiroloculina	x	..	..	..
Spiroplectoides	..	..	..	x
Uvigerina	x	x	..	..

stone (Fig. 4). The Kreyenhagen has a maximum thickness of 1,000 feet in the vicinity of Canoas Creek and Big Tar Canyon, as shown in the generalized columnar section (Fig. 3). It consists of shale with a very few lenticular beds of sandstone and a few lenses or nodules of limestone.

Sandstone is common only at the base of the formation, where the Kreyenhagen shale seems to grade into a transitional zone of friable sandstone interbedded with sandy clay shale tentatively included in the Kreyenhagen. Individual strata range from 1 to 30 feet in thick-

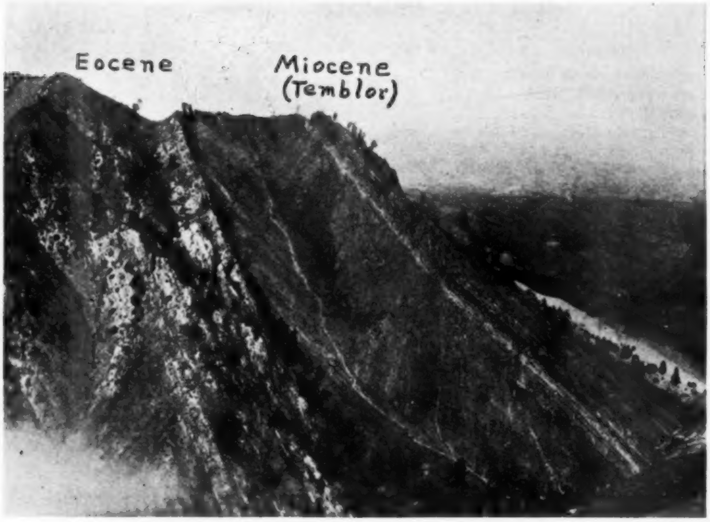

FIG. 4.—The Kreyenhagen shale disappears west of Sulphur Spring Canyon between Miocene (right) and Eocene sandstone (left), probably due to an overlap of the Miocene. At the point from which the photograph was taken the Kreyenhagen shale is 250 feet thick. Looking west.

ness. It is typically a friable, unconsolidated white sandstone, composed of poorly sorted, angular grains ranging in size from coarse to very fine, the fine and medium grains being most plentiful (Fig. 5, *A*). The following minerals are present: plagioclase, orthoclase, microcline, quartz, muscovite, and probably magnetite. Relatively fresh feldspar and quartz predominate in about equal amounts. Microcline is a common constituent.

The large percentage of fresh feldspar does not necessarily indicate arid or semiarid conditions on the land. It is merely evident that the material was not attacked by chemical decomposition. Wave action on a coast might be an explanation for fresh feldspar in a humid, tropical climate. R. D. Reed[1] has recently discussed the question of the high percentage of feldspar in the rocks of the Coast Ranges, with the conclusion that

So far as known at present, then, the average feldspar content of all

[1]R. D. Reed, "The Occurrence of Feldspar in California Sandstone," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 10 (October, 1928), pp. 1023-24.

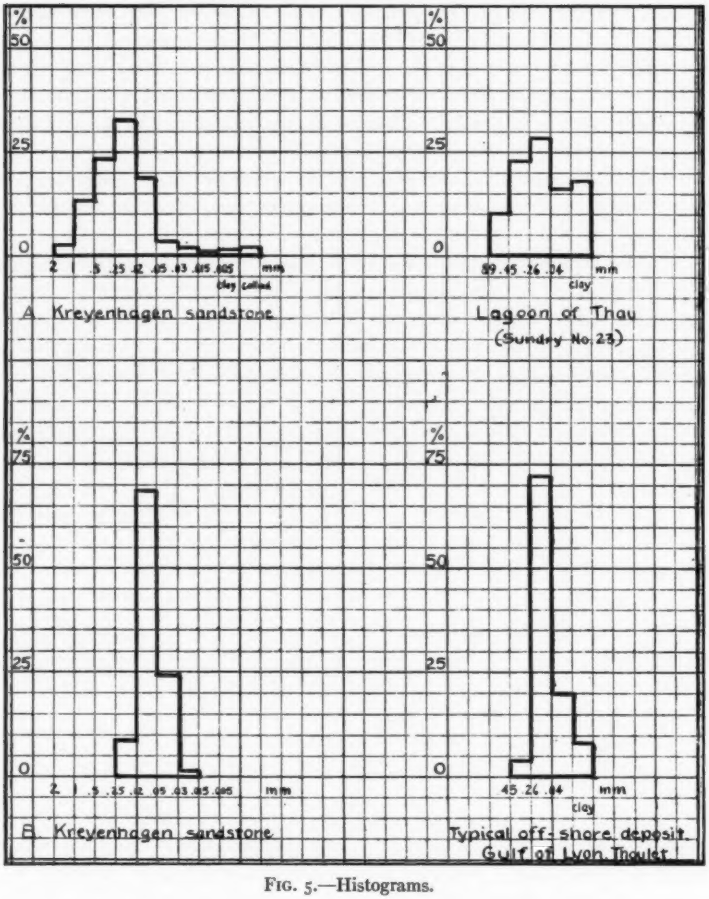

FIG. 5.—Histograms.

Mesozoic and Tertiary sandstones in the Coast Ranges approximates 50 per cent. Sandstones from the Eocene, considered from floral evidence to have been a warm, humid epoch, do not differ appreciably from the normal, or indeed from the supposedly abnormal desert sandstones.

The sandstone interbedded with Kreyenhagen shale is indurated and grayish white on a fresh surface; the grains are angular, very fine to fine in size, and well sorted (Fig. 5, *B*). Quartz greatly predominates

over orthoclase, plagioclase, somewhat altered microcline, and antigorite. Small amounts of chert and hornblende are present.

The presence of antigorite, which is absent in the Domengine sandstone, may partly explain the source of the material; it was probably derived from a deeply dissected region on the west where serpentine and associated rocks, of Franciscan (Jurassic ?) age, now crop out. The absence of antigorite in the Domengine sandstone might suggest that the Franciscan serpentinous rocks were not exposed in pre-Kreyenhagen time.

The transitional zone of sandy shale and sandstone at the base of the Kreyenhagen seems to indicate a gradual submergence rather than an uplift followed by erosion. A histogram shows that the sandstone from the base of the Kreyenhagen resembles most closely Goldman's[1] poorly sorted lagoon type of sand; but it may have been deposited at greater depth because of gravity on a steep slope. The sandstone higher in the section, being of finer grain size and having only one maximum, has the characteristics of an offshore deposit as now known on the margin of the continental shelf, at a depth of 100 fathoms (Fig. 5).

The lenticular limestone occurring in the Kreyenhagen shale is yellow on a weathered surface, but dark gray on a fresh surface. Its maximum thickness is 3 feet. This limestone grades into marl and yellow calcareous shale. The yellow-weathering limestone and shale are limited to the lower part of the formation, but many spheroidal nodules of dark gray limestone, 1-2 feet in diameter, and weathering light grayish, occur in the upper part of the Kreyenhagen shale. The purest lenticular limestone occurs 1 mile south of Big Tar Canyon at a point about 300 feet stratigraphically above the Domengine. Thin sections show a fine crystalline limestone with many radiolarians, 1.9 millimeters in diameter, filled with calcite.

Microscopic study of the impure limestone from different localities and different parts of the section revealed essentially the same features: small angular quartz grains in a matrix of fine crystalline calcite. In addition to the quartz, in one specimen constituting about 10 per cent of the whole, a few fine feldspar grains are present. All the radiolarians are filled with calcite.

The calcareous platy shale, which ordinarily contains *Pecten interradiatus* in profusion, is composed of about 15 per cent of calcium carbonate, the remainder of the material being silt and clay. A few *Fora-*

[1]Marcus I. Goldman, "The Petrography and Genesis of the Sediments of the Upper Cretaceous of Maryland," *Maryland Geol. Survey, Upper Cretaceous* (Text) (1916), p. 170.

minifera are found, fish scales and carbonaceous plant particles are common.

By far the greater part of the shale is siliceous and argillaceous. The color is purplish brown, due to its hydrocarbon content. It differs in hardness, but ordinarily weathers readily; moreover, it is considerably fractured, and cracks are filled with sulphur minerals, gypsum being very common. The bedding is distinct, and in some places rhythmic bedding may be seen. This suggests fairly deep water where wave action is reduced to a minimum. Some silt and very fine sand could be determined in the shale with the aid of the microscope. Among the recognizable minerals calcite and minute angular grains of quartz and dull feldspar are plentiful. Large particles are radiolarians and carbonized wood fragments. No diatoms or fragments of diatoms were noticed.

The shale becomes more siliceous near its top. Just below the contact with the Temblor, in the canyon 1 mile south of Big Tar Canyon, is gray opaline shale, 1-8 feet in thickness; a thin section of this rock shows that, although composed chiefly of opal, a few angular quartz grains and many radiolarians are present. The presence of radiolarians in great profusion makes it seem probable that they may be an important factor in the formation of amorphous silica.

FOSSILS

Mollusca.—Casts and molds of *Pecten interradiatus* Gabb are common in the lower part of the formation. It is the only mollusk recorded in the literature and was first described from the "buff-colored shale east of New Idria, at or near the summit of the Tejon group" (Eocene) where Gabb found it very plentiful.[1] This species belongs to the subgenus *Propeamusium*, the living representatives of which seem to be cool-water forms preferring depths in excess of 50 fathoms. *Propeamusium alaskense* Dall[2] has been reported from Alaska to the Santa Barbara Islands. A specimen of *Propeamusium manaricum* Smith in the Oldroyd collection at Stanford University came from a depth of 401 fathoms in the Gulf of Manar, Ceylon.

Foraminifera.—*Foraminifera* were collected by the writer from the lower part of the Kreyenhagen shale only, as listed in Figure 3.[3]

[1] Ralph Arnold, "The Tertiary and Quaternary Pectens of California," *U. S. Geol. Survey Prof. Paper 47* (1906), p. 54.

[2] W. H. Dall, "Summary of the Marine Shellbearing Mollusks of the Northwest Coast of America," *U. S. Natl. Mus. Bull. 112* (Smithsonian Institution, Washington, 1921), p. 20.

[3] The most fossiliferous locality—that south of Big Tar Canyon—was first called to the writer's attention by R. D. Reed, in a letter to H. G. Schenck, dated December 5, 1928.

Twenty-one genera and 27 species were found, including only one arenaceous form. Most plentiful are the *Lagenidae*, comprising about one-third of the total species. The family is commonly known to be abundant between 50 and 500 fathoms. The genus *Spiroplectoides*, which has not been known on the Pacific Coast as fossil, is somewhat common.

Table I shows the generic assemblage of the Kreyenhagen foraminiferal fauna in comparison with that of other Tertiary formations of the West Coast. A study of this table demonstrates that, even though such a compilation is admittedly incomplete, the assemblage of the Kreyenhagen is more Eocenic than Miocenic. For example, it does not contain the plentiful representatives of *Bolivina, Siphogenerina, Valvulineria, Baggina, Cassidulina, Nonion*, and *Uvigerinella* of the Monterey (middle Miocene) of central California. The foraminiferal fauna of the Temblor (lower middle Miocene) has not yet been described, but a cursory examination of material from the type Temblor proved little similarity with the assemblage of the Kreyenhagen. The distinctive Eocene genus *Discocyclina*, however, is not present in the Kreyenhagen shale. *Miliolidae*, plentiful and varied in the Eocene, are scarce, and such typically tropical forms as *Hantkenina* and *Amphistegina* are absent from the Kreyenhagen.

Many of the Kreyenhagen species have similarities to those described from the upper Eocene of Texas,[1] the upper middle Eocene of California,[2] and the Oligocene of Oregon[3] and California.[4] The Miocene *Foraminifera* of California, however, have little specific resemblance to the Kreyenhagen foraminiferal fauna.

It is interesting to observe a rather close similarity of the Kreyenhagen fauna to Cretaceous *Foraminifera* of the Tampico Embayment[5]

[1]J. A. Cushman and E. R. Applin, "Texas Jackson Foraminifera," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 2 (February, 1926), pp. 154-89.

[2]J. A. Cushman and G. D. Hanna, "Foraminifera from the Eocene near Coalinga, California," *Proc. California Acad. Sci.*, Vol. 16 (1927), pp. 203-29; J. A. Cushman and M. A. Hanna, "Foraminifera from the Eocene near San Diego, California," *Trans. San Diego Soc. Nat. Hist.*, Vol. 5 (1927), pp. 45-64.

[3]J. A. Cushman and H. G. Schenck, "Two Foraminiferal Faunules from the Oregon Tertiary," *Univ. California Pub., Bull. Dept. Geol.*, Vol. 17 (1928), pp. 305-24.

[4]Material from the type San Lorenzo (Oligocene) of Santa Cruz County, not yet described, was used for comparison.

[5]M P. White, "Some Index Foraminifera of the Tampico Embayment Area of Mexico," *Jour. Paleont.*, Vol. 2 (1928), pp. 177-215, 280-316.

TABLE I

Incomplete List of Genera of Foraminifera from West Coast Eocene, Oligocene, and Miocene Formations

Genus	A	B	C	D	E	F	G	H	I
1. Amphistegina							x		
2. Asterigerina(?)				x					
3. Anomalina	x		x		x	x	x		
4. Baggina								x	
5. Bathysiphon					x			x	
6. Bolivina								x	x
7. Bulimina	x	x	x	x	x			x	x
8. Buliminella								x	x
9. Cancris								x	
10. Cassidulina		x	x					x	x
11. Ceratobulimina		x							
12. Cibicides	x	x		x	x		x	x	
13. Clavulina				x					
14. Dentalina	x	x			x	x	x	x	x
15. Discocyclina					x	x			
16. Discorbis						x	x		
17. Epistomina		x		?		x			
18. Eponides	x	x	x	x	x	x	x		
19. Frondicularia									x
20. Gaudryina							x		
21. Glandulina	x		x	x	x				
22. Globigerina	x	x	x	x		x		x	
23. Globobulimina									x
24. Globorotalia					x				
25. Globulina							x		
26. Guttulina	x	x							
27. Gyroidina	x		x	x	x	x	x	x	
28. Haplophragmoides					x	?			
29. Lagena		x				x		x	
30. Lagenonodosaria(?)				x					
31. Lenticulina				x	x	x		x	
32. Marginulina					x		x		
33. Massilina					x				
34. Nodosaria	x		x	x	x	x	x	x	x
35. Nonion		x			x		x	x	x
36. Orbulina								x	
37. Planulina	x					x			
38. Plectofrondicularia	x	x	x	x				x	x
39. Pleurostomella(?)				x					
40. Pullenia								x	
41. Pulvinulinella								x	x
42. Quinqueloculina						x	x		
43. Rhabdamina					x				
44. Robulus	x	x	x	x	x	x	x	x	x
45. Rotalia				x					
46. Sigmoidella		x							
47. Siphogenerina								x	x
48. Siphonina						x	x		
49. Spiroloculina				x					
50. Spiroplectoides				x					
51. Textularia					x	x	x		
52. Triloculina							x		
53. Uvigerina	x	x		x					
54. Uvigerinella								x	x
55. Valvulineria								x	
56. Verneuilina							x		
57. Virginulina								x	

KEY TO LETTERS

A. Bassendorf shale, Coos County, Oregon. Compiled from Cushman and Schenck
B. Keasey shale, Columbia County, Oregon. Compiled from Cushman and Schenck
C. San Lorenzo shale, Santa Cruz County, California. Based upon material collected by D. L. Evans and W. W. Valentine
D. Kreyenhagen shale, Reef Ridge, Fresno and Kings counties, California
E. Domengine Eocene, Fresno County, California. Compiled from Cushman and G. D. Hanna, revised
F. Meganos Eocene, Marysville Buttes, Sutter County, California. Compiled from Stipp, revised
G. Middle Eocene, La Jolla Quadrangle, California. Compiled from Cushman and M. A. Hanna, revised
H. Monterey Miocene, Reliz Canyon, Monterey County, California. Compiled from R. Kleinpell, revised
I. Miocene, Humboldt County, California. Compiled from Cushman and Roscoe E. and Katherine C. Stewart

and the Eocene (?) of Ecuador,[1] suggesting the Gulf of Mexico region as the center of dispersal from which the Kreyenhagen fauna was derived.

This suggestion is supplemented by the resemblance of some of the Kreyenhagen species to the living forms reported by Brady as found at a locality in the West Indies.[2] At this locality, latitude 18°38′ N., the average bottom temperature at 390 fathoms is recorded as 8.3° C., compared with an average of 24.4 at the surface.

Radiolaria.—*Radiolaria*, common all through the Kreyenhagen, but especially plentiful in the upper 350 feet of the shale, belong to the legion *Spumellaria*. They offer little direct evidence as to the origin of the formation, except that marine conditions prevailed. Recent *Radiolaria* are most abundant as pelagic organisms near the equator and prefer normal salinity.

Other fossils.—Fish scales are common throughout the Kreyenhagen, and show that sufficient food was supplied for the fish. Broad-leaf trees existed on the land, as is suggested by a fossil leaf occurring in the Kreyenhagen shale.

A further evidence of life in Kreyenhagen time is the hydrocarbon content of the shale. The theory of the biogenesis of hydrocarbons by diatoms[3] does not seem to be supported by microscopic study of the Kreyenhagen shale. At least it seems doubtful that the siliceous tests of diatoms should not leave any trace of their former existence, although *Radiolaria* are plentifully preserved. However, before arriving at definite conclusions, a study of the silica secreted by diatoms in comparison with that of radiolarians will be necessary. J. de Lapparent[4] observed that the opaline skeletons of radiolarians are ordinarily transformed into an iron-bearing alumino-silicate, and that chalcedony occupies the interstices of some skeletons. However, radiolarian ooze[5] and diatom ooze at present are formed in different areas of the oceans, a fact which also may have a bearing on the problem.

[1]J. J. Galloway and M. Morrey, "A Lower Tertiary Foraminiferal Fauna from Manta, Ecuador," *Bull. Amer. Paleont.*, Vol. 15 (1929), pp. 27 ff.

[2]H. B. Brady, "Report on the Foraminifera Collected by H. M. S. Challenger during the years 1873-1876." *Zoölogy*, Vol. 9 (1884), Plate I, locality D.

[3]C. F. Tolman, "Biogenesis of Hydrocarbons by Diatoms," *Econ. Geol.*, Vol. 22 (1927), pp. 454-74.

[4]Jaques de Lapparent, "Lecons de Petrographie" (Paris, 1923), p. 320.

[5]John Murray and G. V. Lee, "The Depth and Marine Deposits of the Pacific," *Memoirs Mus. Comp. Zoöl., Harvard*, Vol. 38 (1909), p. 155 (Map II).

Recent research on diatoms as a source of oil[1] has shown that aerobic conditions are not favorable to the genesis of petroleum; but under anaerobic conditions decomposition of all the higher fatty acids examined (C_2-C_{18}) could be demonstrated. This agrees with the conclusions reached regarding the origin of the Kreyenhagen shale from faunal and lithologic evidence, namely, a fairly deep, partly land-locked sea in which anaerobic conditions prevailed because of depth and absence of currents.

SUPERJACENT FORMATIONS

TEMBLOR (LOWER MIDDLE MIOCENE)

In the region of Canoas Creek and Big Tar Canyon, the Temblor sandstone rests without angular unconformity on the eroded surface of the Kreyenhagen shale. Pebbles of siliceous shale at the base of the Temblor were evidently derived from the underlying Kreyenhagen. The total thickness of the Temblor is about 1,050 feet, 1 mile south of Big Tar Canyon. The lower part is mainly soft, shaly sandstone, in which occur fossil bones and shark teeth; the sandstone is typically gray, fine- to coarse-grained, and resistant to weathering.

Near the middle, the formation is very fossiliferous; it contains a shallow-water marine fauna including many pelecypods and gastropods, such as *Turritella ocoyana* and *Pecten andersoni*, which also occur in the Temblor beds north of Coalinga and are considered characteristic of the Temblor (lower middle Miocene) horizon. Arnold and Anderson[2] used the name Vaqueros for this part of the Miocene section because they were of the opinion that the Temblor is the equivalent of the Vaqueros; but according to most present-day stratigraphers the Temblor formation is younger than the Vaqueros, the lowest Miocene horizon recognized in California.

SANTA MARGARITA (?) (UPPER MIOCENE)

The Temblor sandstone of Reef Ridge is overlain by siliceous shale, tentatively referred to the Santa Margarita by Arnold and Anderson.[3] This shale overlaps upon the Kreyenhagen and older formations at the southeast end of Reef Ridge.

CONCLUSIONS

Available data suggest that the Kreyenhagen shale of Reef Ridge was deposited in marine water of normal salinity, at a depth of 50 fathoms

[1] L. B. Becking and C. F. Tolman, "Diatoms as a Source of Oil," *Bull. Amer. Petrol. Inst.*, Vol. 10 (1929), p. 7.

[2] *Op. cit.*, p. 80.

[3] *Op. cit.*, pp. 90-96.

or more, and the upper half of the formation perhaps within the bathybic range of 100-500 fathoms. The bottom temperature of the water was cool, approximately 8° C., although the climate on the land may have been subtropical. It is believed that a land mass existed at the west which was deeply dissected during Kreyenhagen time, so as to expose rocks of Franciscan (Jurassic) age.

Although the exact age of the Kreyenhagen is not yet established, its stratigraphic position between the Domengine (upper middle Eocene) and Temblor (lower middle Miocene) proves that it is upper Eocene, Oligocene, or lower Miocene in age. Paleontologic evidence, as well as an unconformity between the Kreyenhagen and the Temblor, suggests that the Kreyenhagen shale is of Eocene or Oligocene, rather than Miocene, age.

PHYSICAL ANALYSIS OF OIL SANDS[1]

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ABSTRACT

Since the work on rock and grain densities by A. F. Melcher at the United States Geological Survey, described by him in 1920, various improvements and refinements have been introduced in the methods and apparatus used there. A new form of precision pycnometer and new methods are described, with a simple method of measuring permeability. Common sources of error and the interpretation of results are discussed in some detail.

A knowledge of the grain size distribution, grain density, rock density, porosity, and permeability of oil sands is of widespread interest in petroleum field engineering and finance. Methods of determining these quantities have been given considerable attention. Although such methods involve only elementary physical principles, they are full of pitfalls for the unwary and many published papers bear mute evidence to the lack of suitable guidance or experience among those attempting such determinations.

Much has been done in improving methods of testing and in adapting special methods to special materials. The writer will not attempt a review of the voluminous literature. An excellent method for finding the densities and porosities of oil sands was developed and described by A. F. Melcher in 1920.[3] During the past 5 years his method has been improved and shortened in many ways. As no further improvements are in prospect, it seems fitting to describe the methods now in use at the Survey, to call attention to serious errors commonly made, and to discuss the interpretation of test data.

GRAIN SIZE ANALYSIS

Nearly all oil sands and limestones are of the sandstone type,—few incoherent and few so firmly cemented that the grains may not be separated without being broken. The size-distribution curve is an important

[1]Manuscript received by the editor, May 29, 1930. Published by permission of the director, U. S. Geological Survey.

[2]U. S. Geological Survey. Introduced by David White.

[3]A. F. Melcher, "Determination of Pore Space of Oil and Gas Sands." August, 1920, meeting, A. I. M. M. E., *Trans. A. I. M. M. E.*, Vol. 65 (*Oil and Gas*), pp. 469-97. *Abstr. Min. and Met.*, April, 1920, p. 31.

characteristic of many sands and may serve to identify them if the sequence of overlying strata is broken or unknown. It ordinarily has an important bearing on porosity, permeability, and recovery problems.

There are two prime essentials in size analysis, an accurate set of standard sieves and means of separating all individual grains without crushing any.

1. *Standard sieves.*—Of the many sets of sieves on the market, only those forming a logarithmic sequence are of service in obtaining size-distribution curves. The opening in each sieve must be a constant fraction of the opening in the next coarser sieve. In the set made by Tyler, Cleveland, the constant ratio is $\sqrt{2} = 1.41$, so that each second sieve has twice or half the opening. The lower limit of fineness is the 300-mesh opening 0.052 millimeters square, and even this is so weak that it must be carefully handled. Limits of tolerance in variation of size of opening must of course be narrow. Standard sieves are made of copper or bronze wire with warp and woof exactly alike, both being bent so that each wire is immovable.

Most of the material passing the 300-mesh is ordinarily cementing material, possibly a soft coating (Big Injun) and not worth further size analysis. In a few places in which the curve maximum is below 300-mesh (lower Wietze, Hannover, Germany; Barney Mills, New York; Shoestring, Garnett, Kansas; and a few others), further analysis would be of interest, but means are not yet available; bolting cloth is not properly spaced as to size, and elutriation with water is laborious and uncertain. Air separation is coming into use by cement manufacturers and seems promising.

The mesh and opening of the Tyler set of standard sieves are as follows (Table I).

TABLE I

Mesh	*Opening (Millimeters)*	*Mesh*	*Opening (Millimeters)*
300	0.052	35	0.417
200	0.074	28	0.589
150	0.104	20	0.833
100	0.147	14	1.168
65	0.208	10	1.651
48	0.295	8	2.362

Amounts of material passing 300-mesh and remaining on each of the other sieves are weighed and reduced to percentages.

2. *Separation of grains.*—The ordinary procedure is to break about 1 cubic inch of material into small lumps with a hammer. Care is required to avoid breaking grains by too violent pounding. The material is ground finer with a porcelain mortar and pestle to pass the coarsest sieve, perhaps 35-mesh. From that size down to the 150-mesh sieve the material is worked through with the pestle directly on the sieve. This can be done without breaking the quartz grains, but can not be done in the mortar. The rubbing on each sieve must be continued until no more grains go through and no more dust shows from cementing material or grain coatings. The microscope must be used to determine when the work on each sieve is complete. Each sieve is finished ordinarily with the bare fingers to secure the best rubbing action.

The finest three sieves (150, 200, and 300-mesh) are worked with the bare fingers. A solid rubbing tool crushes some grains; sole leather or rubber is not effective. The greatest care and patience are required to get a satisfactory separation and any other is a waste of time. About an hour is usually spent on six sieves. However, although the sandstones and limestones may be very hard, surprisingly satisfactory and reproducible results may be obtained, if sufficient care is used.

Size analysis, of course, is not feasible if the cementing material is harder than the grains, but few oil sands show this condition. If a clay filling has hardened to shale, the lumps are easily mistaken for grains, but all must be worked through a 300-mesh screen for a true analysis. One such material yielded a satisfactory analysis after being soaked in water for a week. Roasting softens some rocks but hardens others. The relatively soft grains of calcite, siderite, various micas, chert, tourmaline, gypsum, serpentine, and similar minerals, commonly occurring in oil sands, are not ordinarily firmly cemented by harder material. If they are, segregation can be accomplished only after softening the cementing material by soaking in water, very dilute alkalis, acids, or salt solutions. Furthermore, it must be admitted that the distinction between a true grain and a composite lump can not be precisely drawn in general terms. One sand has been observed in which grains as small as 0.1 millimeter were very hard conglomerates of much finer grains.

3. *Size-distribution curves.*—Data on percentages of each size should be plotted, not only for ready reference, but to verify the analysis. A curve that is not smooth is *a priori* evidence of an incorrect analysis; either grains have been crushed by too vigorous grinding, or lumps have

not been worked down to ultimate particles. A shoulder on the curve indicates that one sieve has not been as thoroughly worked as the others. True secondary maxima occur very rarely.

Various systems of plotting size-distribution curves have been suggested and used. The cumulative curve is neat in appearance, but hides errors and fails to bring out true characteristic differences. Plotting percentages against actual grain dimensions means a curve so extended as to be useless. The most natural and most rational and useful method is to plot percentages against logarithmic sizes or simply sieve numbers. Abscissas are numbered 1, 2, 3.... corresponding with sieves of 300,200, 150.... mesh.

The method of plotting and reducing observations is illustrated by some selected data tabulated as follows (Table II) and plotted in Figure 1. The first four are typical of oil sands; the fifth and sixth are typical of the very coarse gas and tar sands.

TABLE II

Mesh	*Opening (Millimeters)*	*Wietze*	*MR 13*	*Big Injun*	*SL 20*	*"Temblor"*	*Lakota*
Through 300	0.052	11.43	13.61	13.68	1.78	5.13	4.30
On 300	0.052	57.36	22.76	5.43	4.09	4.25	0.70
200	0.074	29.53	51.49	7.98	6.56	4.63	1.02
150	0.104	1.68	12.14	53.78	24.72	15.64	1.76
100	0.147	0.00	0.00	19.13	52.00	36.21	3.72
65	0.208			0.00	10.86	27.33	30.35
48	0.295					6.82	52.83
35	0.417					0.00	5.33
Maximum at sieve		(1.6)	2.58	3.56	4.45	4.82	6.38
Grainsizemax.(mm.)		0.064	0.090	0.127	0.172	0.196	0.336
Spread		(1.4)	1.55	1.32	1.65	2.25	1.60
Skewness		(0.45*L*)	0.67*R*	0 75*L*	0.65*R*	0.88*R*	0.65*R*

In plotting such curves it would be desirable to have more points near the maxima and such points might be obtained were intermediate sieves (in steps of fourth root of 2) available. However, with only data from the present sieves, the curves may be sketched with only a slight uncertainty, which is generally quite immaterial. The position of the maximum is readily located on coördinate paper graduated in tenths. To this reading 0.50 must be added because the material resting on a sieve ranges in size from that sieve opening to the next larger. A curve maximum at 2.08 on the plot is, for example, really at 2.58.

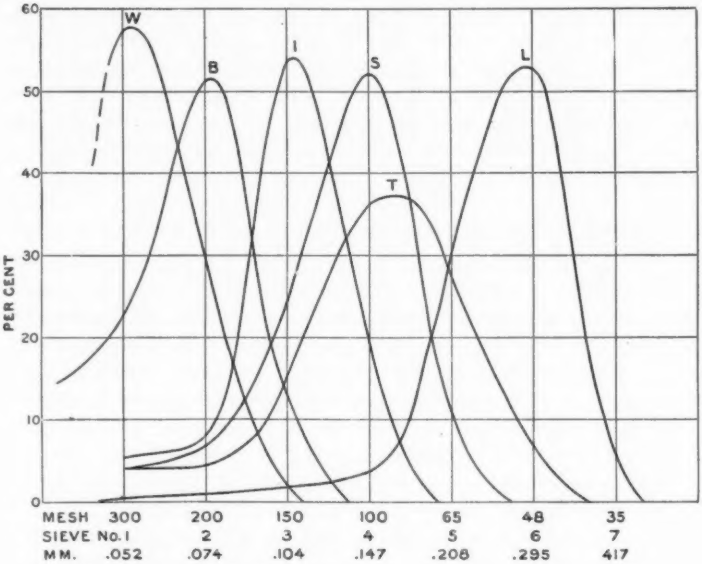

FIG. 1.—Plotted size-distribution curves.
Curve *W*, fine lower sand, Wietze, Hannover, Germany. *B*, typical fine hard Bradford, Pennsylvania, sand, Minard Run 13. *I*, Big Injun sand, West Virginia; fines form a white coating of siderite on the grains, though in *W* and *B* they are chiefly still finer quartz grains. *S*, coarse very lightly cemented Bradford sand, R. & R. State Line 20. *T*, typical coarse "Temblor sand" from Kettleman Hills, California; fines, principally carbonates. *L*, Lakota gas sand, Lance Creek, Wyoming; fines, chiefly infiltrated clay. The abscissas used are indicated.

Sieve numbers (n) are reduced to millimeters (s) by means of the relation (applying to the Tyler standard set)

$$n = 9.5225 + 6.6439 \log S$$

For the sieve number $n = 2.58$, $\log S = -1.0449$ or $S = 0.0902$ millimeters. The "spread" of the curve (Table II) is simply the width at half the maximum height. The "skewness" is a measure of its dissymmetry, the ratio of the right and left components of the spread measured from the position of the mean. The datum 0.67R means that the curve "leans" toward the right, the right spread being two-thirds as extensive as the left. The location and height of the maximum as well as spread and skewness are useful for purposes of identification. There are more exact methods of finding these quantities by calculation, but they are so laborious as to be of little service in this field.

A close microscopic or even chemical examination of the material passing 300-mesh is generally fruitful. Much of this material is of the same nature as the coarser grains, mixed with a little true cementing material. It may be clay, down to colloidal fineness, very hard if so plentiful that it has had to support great pressures, but ordinarily soft. Carbonates, soluble in acid, are plentiful in a few sands.

DENSITY AND POROSITY

Densities are determined by weighing in air and in water or other liquid and dividing mass by volume. Pore space is unity less the ratio of lump density to mean grain density, or it may be determined by finding the difference between lump volume and grain volume and dividing by the lump volume. A wide variety of methods and apparatus for making the necessary measurements are available. Inasmuch as both density and porosity depend upon differences, results of value can be determined only by methods capable of considerable precision and by the exercise of great care in avoiding spurious effects. Improvements developed at the Survey during the past 5 years have increased the precision approximately ten times and shortened the work by about one-half.

1. *Lump density.*—The mass of the lump is of course determined by weighing with ample precision. Questions arise only concerning selection of a sample and freeing its pores from water and oil without disturbing water of crystallization, reducing salts to oxides, or carbonizing hydrocarbons. The lump should be homogeneous and enough adjacent material and trimmings from the lump itself should be saved to serve for determining grain density. Conditioning the material is discussed at the end of this section.

Finding the true external volume of a lump of porous rock with high precision is extremely difficult. Melcher[1] coated his lump with paraffine and found the loss in weight if suspended in water. Athy[2] submerges the lump, without paraffine coating, in mercury, obtaining its buoyancy by weighing. Comparing this method with Melcher's, he obtains consistently slightly smaller volumes than when the paraffine coating is used. In either method there is a slight and uncertain capillary effect around the suspension.

After working with these and other methods for several years, the writer has adopted a pycnometer method using a paraffine-coated lump in a new form of pycnometer specially designed for this class of work.

[1] *Op. cit.*

[2] L. F. Athy, "Density, Porosity, and Compaction of Sedimentary Rocks," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 1 (January, 1930), p. 3.

Capillary effects are eliminated and volumes may readily be determined to 1 part in 10,000. The same pycnometer serves for both lump and grain density, thus eliminating several weighings and corrections.

The new pycnometer (Fig. 2) is a low, wide cylindrical vessel, 30 millimeters in diameter and 20 millimeters deep, provided with a flange 4 millimeters wide on which rests a circular plate-glass cover 2 millimeters thick and 38 millimeters in diameter. The top of the flange is ground and polished optically flat so that the cover defines a precise volume (about 15 cubic centimeters) and evaporation during weighing is negligibly small. The large mouth permits the use of a large (6 centimeters) lump of material. The cover, 2 millimeters thick, is so stiff that errors in volume due to pressure are well under that of 1 milligram of water. This form of pycnometer permits rapid and thorough cleaning. The preferred size and form of lump are nearly cylindrical, 1 inch in diameter, and 3/4 inch thick, with all corners and edges well rounded on a coarse carborundum hone. A 2×2×8-inch rail- or rock-planing bit is a very useful tool in a rock laboratory. Sharp projections are very difficult to make water-tight with paraffine. The best coating process has been described by Melcher. The paraffine should be just melted; if too hot it enters the pores. While still warm, the paraffined lump is worked in the fingers to press the coating home. Considerable retouching with a wire is generally necessary to close all holes.

Volume is determined from the weight of water displaced by the lump, the weight of 1 cubic centimeter of distilled water being

At 15°, 0.99910 gram	At 25°, 0.99704 gram
At 20°, 0.999820 gram	At 30°, 0.99565 gram

The density of paraffine is near 0.90 gram per cubic centimeter and should be re-determined frequently in precise work. Temperature of water and paraffine are taken at the time of weighing, a thermostat being unnecessary unless room temperatures are changing very rapidly. Water saturated with air is heavier by about 20 parts per million. A sample determination follows.

Weight of lump	15.1904 grams
Weight paraffine-coated lump	15.6809 (paraffine, 0.4905 grams) = 0.5450 cc.
Pycnometer empty	14.9256 grams
Pycnometer water-filled	27.7071 (water, 12.7815 grams) = 12.8161 cc.
Pycnometer+lump+water	36.4904 grams
Pycnometer+water+weight lump	43.3880 grams
Water displaced by lump	6.8976 grams = 6.9173 cc. = vol. paraffine lump
Volume of lump itself	6.3723 cc. = 6.9173 − 0.5450 cc.
Lump density	$\frac{15.1904 \text{ grams}}{6.3723 \text{ cc.}} = 2.3838$

FIG. 2.—The new pycnometer. At left, the pycnometer empty, with cover removed; center, in use with paraffined lump in water; right, in use with grains in tetralin.

2. *Grain density.*—Grain densities are preferably determined with the same special pyconometer used for finding lump densities, but the flat-top bottle type designed by Johnston and Adams[1] and used by Melcher is quite satisfactory except that changing pycnometers means extra weighings and that the bottle form is not as easily cleaned or filled. Pycnometers with tapered ground joints are of course useless for any precise work because of the uncertainty in the volume defined.

The grains used for density determination should be specially crushed and passed through a single sieve of 65 or 100-mesh. Some crushing of the coarser grains is not objectionable, but lumps larger than 0.15 millimeters are undesirable. It is unsafe to use the grains separated in the size analysis, because it is difficult to procure a correctly mixed sample of this material. The only serious difficulty in finding grain densities is in getting rid of all bubbles. With water as a pycnometer fluid it seems almost impossible even with extended vacuum treatment. Many other liquids that wet the grains nicely are too volatile, are too expensive, or are otherwise objectionable. Pure turpentine (pinene) was used for some time, but its too ready polymerization with rapid changes in density caused its rejection in favor of tetralin (tetrahydronaphthalene). Tetralin is a clear limpid liquid of high boiling point (205° C.), with density about 0.98, which, being a solvent for both water and hydrocarbons, wets grains of all sorts readily despite adsorbed films of any nature.

In practice, the pycnometer is filled nearly full with the dry grains conditioned as desired, then the tetralin is poured in very slowly at one side until the grains are well covered. A little gentle agitation with a wire releases the few entrapped bubbles, and when no more appear, the cover is slipped on. The procedure varies somewhat from that for lump density as shown by the following sample.

Weight of pycnometer,	14.9258 grams
Pycnometer + dry sand,	22.5201 (sand, 7.5943 grams)
Pycnometer+sand+tetralin,	32.2187 grams
Pycnometer water-filled,	27.7137 (water, 12.7879 grams) = 12.8210 cc.
Pycnometer tetralin-filled,	27.4235 (tetralin, 12.4977 grams) = $0.9748 \frac{\text{grams}}{\text{cc.}}$
Pycnometer+sand+tetralin,	35.0178 grams
Tetralin displaced,	2.7991 grams = 2.8715 cc. = volume sand
Sand grain density,	$\frac{7.5943 \text{ grams}}{2.8715 \text{ cc.}} = 2.6447$

3. *Porosity.*—The volume of the void spaces in a rock or sand is a fraction of the whole volume, termed the porosity, or more strictly the void

[1] *Jour. Amer. Chem. Soc.*, Vol. 34 (1912), p. 566.

fraction, the voids having no mass. The solids represent that fraction of any specified volume which is the ratio of the lump and grain densities; hence, porosity is the ratio, $1-$lump density: grain density. In the example cited, the ratio, lump density: grain density $= 2.3838 : 2.6447 = 0.90135$, which is the fraction of any volume occupied by grains. The porosity is therefore 0.09865, or 9.865 per cent. As defined experimentally, it includes all pores into which the pycnometer fluid enters in finding grain density; hence, the importance of rather fine grinding and of a pycnometer fluid having powerful wetting properties but not strongly absorbed by minerals.

The adsorption of water by quartz is easily measurable and may cause an error of 1 or 2 per cent in the apparent grain density of very finely powdered material. The adsorbed film is about 10^{-5} millimeter deep and has a density of about 1.3. Turpentine is strongly adsorbed by many minerals, a property which makes it useful in paints. Many oil sands have an adsorbed tarry coating not removable by the most powerful solvents and only with great difficulty by ignition. Chromic acid removes it ("wet combustion") and soaking in oil for 8-12 hours restores it. The Tensleep sand of Wyoming, a pure quartz sand, exhibits these properties. A good pycnometer liquid should be only lightly adsorbed.

The question of the proper conditioning of a sample before determining lump or grain density can not be answered in general terms. Obviously, oil and free water should be eliminated before weighing and before finding grain volume. A coarse quartz sand or coarse limestone is simply ignited over a bunsen flame (about 800° C.) and cooled in a desiccator. The common carbonates break down to oxides only very slowly at ignition temperature. Even a prolonged washing in hot solvent in a Soxhlet extractor is very ineffective on lumps of oil sands. On a shale, an oven treatment at 200° C. was found to be the best preliminary to density determinations. Deduction of the ignition loss on the grains from that on the lump gives an approximate measure of oil content and possibly (with porosity) of saturation, but good quantitative results can be obtained only by the chemical method of collecting and analyzing the gases evolved. In many minerals a temperature of 300° C. is necessary to drive off even 90 per cent of the free and adsorbed water. Preliminary tests to determine the nature of an unknown sand are without exception desirable.

Most oil sands lose 2-8 per cent in weight on ignition, aside from the oil content, due to loss of water. As the volume of a lump is but little

affected, there is a corresponding loss in density. Few oil sands contain considerable amounts of clay material, but if they do contain clay, volume changes on ignition are appreciable and may be considered. Ignition increases grain density if such fine material, whether silica or not, is present. Ignition drives off both free and hydroxyl water and even room-dried grains take up considerable *OH* from liquids such as water or alcohol, which contain them. It is probably the adsorption or surface union of silicates with hydroxyl ions, setting free hydrogen, which causes the persistent evolution of gas (hydrogen) bubbles when water is used as a pycnometer liquid. An ideal pycnometer liquid would be one which gave nothing to the grains and dissolved from them any moisture or oil without increase in its own volume. Much remains to be done in developing methods for the pycnometry of clays and shales.

The field instrument developed by Russell for finding porosities, measures volumes directly by fluid displacement, obviating all weighings. A large ground joint is essential for introducing material, the lump material must be crushed without loss to find grain volume and temperature changes, and drainage in the stems causes considerable uncertainty. It does not seem possible to make refinements that would make it a precision instrument.

PERMEABILITY

Resistance to the flow of fluids through porous rock material is of widespread interest in geology and of especial interest in petroleum recovery problems. The determination of permeability, like the measurements previously discussed, is very simple in theory but beset with minor difficulties. In principle, a plate of the rock to be tested is subjected to a known pressure difference and the rate of flow measured. From the dimensions of the test plate, the pressure gradient, viscosity, and rate of flow, the specific permeability is readily computed.

A small test plate requires less labor in its preparation and there is less danger of leakage around it during test. The standard size in testing oil sands at the Survey is 5.0 millimeters thick and about ½ inch in diameter. This is carefully coated around the edge with sealing wax and cemented over a 10-millimeter round hole in an ordinary pipe cap —the cast-iron bowl used by plumbers to cap blind pipe ends. This cap is then screwed onto a pipe angle and that onto a T attached to a sink tap; the other side of the T is for attaching a pressure gauge. Tests with liquids other than water (oil, salt solution, et cetera) are provided for by inserting a valve joint back of the cap and filling between cap and valve with any special liquid to be used before attaching to the pressure tap.

The tap pressure at the Survey is very constant at 85 pounds so that the gauge is seldom used. Air pressure is used by some, but is not so easily kept constant and tends to force air into solution. For very precise laboratory investigations, a gravity head is used.

Flow is measured by catching the drip for a few minutes in a graduate. Because the rate of flow falls off rapidly (ordinarily to about one-half in an hour), the measurement is begun as soon as the flow is full and steady. About 2 cubic centimeters per minute is an average rate for an average oil sand with the pressure and test disc described. A flow of less than 0.01 cubic centimeter per minute is uncertain unless protected from evaporation.

The test disc is roughed out from the selected sample of core either with a chisel or with a small core drill in a drill press, then worked down to dimensions on a coarse carborundum stone. In many special tests no consistent difference in permeability between horizontal and vertical sections has been shown. It was at first thought that grinding débris carried into the pores was the cause of the rapid fall in permeability, but check tests in which the inner face of the test piece was an unground cleavage face showed this not to be the cause. Immediately before beginning a test, the inner face is rinsed, the outer face being kept dry to avoid choking the pores with a mixture of air and water. It seems to make little difference in the permeability measured whether the test piece has been air dried, filled with crude oil, or washed out with gasoline. Boiling the test piece in soda solution does not greatly affect the initial permeability, but prevents for some time the falling off in rate of flow. Ignition of the test piece ordinarily almost doubles initial permeability and inhibits its falling off for about an hour. The same fall in permeability with time has been found to occur if air-free distilled water is used for the test or if a water-bearing sand that never contained oil is used. It is apparently due to the readsorption in the pores of hydrolyzed silica in the water. Investigators elsewhere have recently shown that it does not occur in alundum (sintered Al_2O_3) disks if the water has been purified through similar disks or has been condensed and stored in paraffine-lined tubes and bottles.

The rational C. G. S. measure of permeability, namely, the flow in cubic centimeters per second through each square centimeter, of a fluid of unit viscosity under a pressure of 1 dyne per centimeter, is too small for convenience. A standard viscosity of 0.01 corresponding with water at 20° C. (68° F.) and a pressure gradient of 1 megadyne (1.02 kilograms weight) per centimeter, or 15.45 pounds per square inch per

centimeter, is more convenient. Permeabilities obtained with the standard Survey apparatus here described expressed in cubic centimeters per minute through a disk 10 millimeters in diameter, 5 millimeters thick, with a pressure of 85 pounds, may be reduced to absolute units (cc./sec./cm.^{2} per megadyne/cm.^{2}/cm.) by dividing by 553. The viscosity of water is

0.0114 at 15° C.	0.0089 at 25° C.
0.0100 at 20° C.	0.0080 at 30° C.

There is no essential relation between permeability and porosity. Many water-tight (except for hydration and diffusion) shales have porosities as high as 35 per cent and some oil sands having porosities as low as 15 per cent are very permeable. Oil sands having natural packing, as though shaken down loose, are exceptional (Bartlesville, Tensleep). Such sands have a mean pore diameter[1] about one-fifth the mean grain diameter. In the ordinary sands the pores are much larger and fewer, larger than the grains in mean size as though dissolved by percolating water.

In certain Bradford and other sands recently investigated at the Survey, a plot of permeability against mean grain diameter gave a smooth parabolic curve cutting the axis (permeability 0) at a grain size of 0.07 millimeter, indicating that finer sands, of this series at least, would be impermeable to water. Later a sand (Barney Mills, New York, 804 feet) was found that was just below the limit in mean grain size. Under test, this sand was easily permeable to gasoline and to crude oil, but not to water, the pores being effectively choked by absorbed water. Much interesting and valuable research remains to be done in the field of permeability.

[1]P. G. Nutting, "The Movement of Fluids in Porous Solids," *Jour. Franklin Inst.*, Vol. 203 (February, 1927), pp. 313-24.

GEOLOGICAL NOTES

DISCOVERY OF OIL IN SAXET GAS FIELD, NUECES COUNTY, TEXAS

Dunn No. 6 of the Saxet Oil Company, the first oil well in the Saxet gas field, Nueces County, Texas, 5 miles west of Corpus Christi, on the south shore of Nueces Bay, drilled the plug and penetrated 11 feet of sand with some shale from 4,297 to 4,308 feet on August 9. Before being conditioned the well was making about 85 per cent salt water and its oil production was variously estimated as ranging from 25 to 300 barrels. The oil is 24° Bé. and closely resembles that from the Refugio oil field at 3,700 feet, with flash point of 205, fire, 230, 23 per cent gas oil, 77 per cent fuel oil. The well is in the northern part of the field, probably on the northeastern slope of the structure. Showings of oil have been encountered at depths between 1,200 feet and 4,100 feet in four wells in the gas field. Gas is produced in several sands from 1,700 to 4,100 feet. Gas sands commonly carry water, making between 20 and 200 barrels, or more, per day. Nearly all proved gas acreage is held by the Saxet Gas Company.

The gas field was discovered when the Pioneer Meaney No. 1 blew gas to atmosphere at high pressure. The first commercial well, Dunn No. 1, was drilled in 1923 by W. L. Pearson and associates on a location made by D. M. Cashin. Location was 1,800 feet from the Pioneer well and was made on trend from White Point, 4 miles north across Nueces Bay, where several gas blowouts had been encountered in wells drilled for oil.

Location for the Dunn No. 6 oil well was made by W. L. Pearson and W. Armstrong Price, 1,000 feet from the Dunn No. 5, which had a showing of oil at 3,380-3,387.

W. Armstrong Price

Houston, Texas
August, 1930

RICHMOND FOSSILS IN KANSAS VIOLA

Fossils recovered from cores of the Kansas "Viola" in an Empire Oil and Refining Company well, Sec. 19, T. 26 S., R. 5 E., El Dorado

field, Butler County, Kansas, have been identified by E. R. Cumings, Indiana University, as *Rhynchotrema capax*, *Dalmenella meeki*, and a species of *Dinorthis*, all Richmond forms. They are not perfectly typical, and Dr. Cumings states that "only the *Rhynchotrema* is well enough preserved to make an identification at all certain, and this, though smaller, seems to be very close to *R. Capax*."

This substantiates correlation with the Viola of the Oklahoma Arbuckle mountain section. Placing it in the Richmond or upper Viola, however, is contrary to the present belief of some who regard the Kansas "Viola" as Trenton or middle Viola of the Arbuckles.

The formation is present under most of eastern Kansas, occurring directly above the Kansas "Wilcox," or Simpson formation. It is easily identified where cuttings including formations above and below are available. It is a brown, cherty, coarsely crystalline dolomitic limestone, 20 feet thick where the fossils were obtained.

These determinations are submitted as an aid to those interested in determining correlation of the Kansas Ordovician.

Robert L. Kidd

Empire Companies
Bartlesville, Oklahoma
September 3, 1930

DEVELOPMENT OF GEOLOGICAL SURVEY BY CALIFORNIA STATE DIVISION OF MINES

Since July, 1930, the California State Division of Mines has developed a geological survey as part of its organization. Through the efforts of the state mineralogist, Walter W. Bradley, the geologic branch has been able to make an auspicious beginning on an interesting 10-year program of work. The cordial support of various institutions, organizations, and individuals has enabled the chief geologist to arrange for a very fundamental research. It is hoped that full support will come from every quarter to encourage further progress.

Through a program of coöperation the State is getting much work done for a very small expenditure. Only $20,000.00 for the first biennium was granted for the geologic branch, and now the second year of that biennium is partly gone. The extent of the work, however, has grown very large, and the credit for the actual progress should be given to the enthusiastic contributors to the new undertaking who have been working only for the sake of doing something worth while.

The new bibliography of the geology of California, a very extensive piece of work, prepared by Solon Shedd of Stanford University, has now gone to press.

The compilation of the new state geologic map of California (scale 1:500,000, or about 8 miles to the inch) is well under way and it is planned that the map shall be engraved under the editorship of George W. Stose, of the United States Geological Survey in Washington, D. C. The base of this map has already been issued by the Federal Survey.

Twelve geological field parties worked during the summer under the auspices of the State Geological Survey. Detailed geologic surveys or studies have been made in these areas.

1. Weaverville Quadrangle (Trinity and Shasta counties) by N. E. A. Hinds, assistant professor of geology, University of California.

2. Shasta Quadrangle (Siskiyou, Shasta, and Trinity counties) with special reference to economic developments, by Charles V. Averill, district mining engineer, State Division of Mines. An areal geologic map of the quadrangle has been supplied by the geological department of the Southern Pacific Company, and Mr. Averill is coördinating this work with his own.

3. Searles Lake Quadrangle (San Bernardino, Inyo, and Kern counties) by Carlton D. Hulin, associate professor of geology, University of California.

4. Elizabeth Lake Quadrangle (Los Angeles and Kern counties) by Edward C. Simpson, University of California.

5. San Jacinto Quadrangle south of San Gorgonio Pass (Riverside County) by Donald M. Fraser, Columbia University.

6. Part of San Bernardino County, including the Ship, Marble, and Providence mountains, by John C. Hazzard, University of California.

7. Part of San Bernardino County, including the Newberry Mountains, by Dion Gardner, University of California.

8. Region on the east flank of the Sierra Nevada in Mono County, by Evans B. Mayo, formerly of Stanford University, now of Cornell University.

9. Mineral deposits of the Minarets district in northeastern Madera County, by Homer Erwin, University of California.

10. Sebastopol and Duncans Mills quadrangles, west of the Santa Rosa Quadrangle (Sonoma and Marin counties), by F. A. Johnson, University of California.

11. The deeper mine workings in the Grass Valley district, by Robert L. Loofbourow, Stanford University, working as assistant to the U. S. Geological Survey, in a coöperative arrangement with the State.

12. The coast tunnels of the Hetch Hetchy aqueduct (San Joaquin and Alameda counties), by George L. Green, Stanford University.

A more extensive program of coöperation with the Federal Survey is planned for the future. Both topographic and geologic surveys are to be made in regions of the state where little work has previously been done.

In order to complete the new state geologic map in advance of detailed reports, many geological departments of commercial concerns have offered to assist in checking the compiled map and contributing new data in areas now remaining nearly blank. The map will be issued, it is planned, in three parts, the 39th parallel separating northern California from central, and the 36th parallel separating central California from southern. The southern sheet will probably be issued first, as there is more information available in that part of the state.

The older state map issued by the State Mining Bureau in 1916, prepared by James Perrin Smith, is still serving a useful purpose in depicting the general features of the geology of California. The new map, however, will be on a larger scale and will show the geology in greater detail. About 26 per cent of the state is included in published detailed and semi-detailed geologic maps, 32 per cent in unpublished but available material, and 42 per cent remains practically blank. Much of the blank area has not even been included in topographic surveys.

The name *Geological and Economic Mineral Survey* has been adopted by the State Mining Board for this branch of the Division of Mines. It is felt that the geologic study and the geologic maps in preparation are fundamental to the economic development and conservation of the state's mineral resources, and that information of this character should be made available to the people of the state. Encouragement for early publication is especially desired. In the organization and development of this geological survey for a state as large as California there is, naturally, a necessity for coöperation from all those interested. The object of the undertaking is to encourage systematic study, the coördination of interests, and the making available of geologic data of general and regional value. It is the desire of the geologic branch of the California State Division of Mines to keep in close touch with all geologists and geological

organizations interested in California and to know of their progress in scientific research.

The following resolution adopted at a mining congress held in Weaverville, July 7, shows the attitude of the Northern Chapter of the Mining Association of California, and of the State Chamber of Commerce.

Whereas, much has thus far been accomplished and yet more promised for the future by coöperation with the State Division of Mines, of the U. S. Geological Survey, the geological departments of the University of California, Stanford University, and other universities in this state, by the geological departments of the Southern Pacific Railroad Company, and a number of the oil companies, in the geological survey of California now in progress,

Therefore, be it resolved, that the Northern California Chapter of the Mining Association of California hereby commends the geological survey of California thus undertaken, and heartily commends the coöperative attitude and work of the several agencies aforesaid; and we furthermore recommend to the responsible agencies the publication of the results of field studies at as early dates as possible as the work progresses.

OLAF P. JENKINS

CALIFORNIA STATE DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO, CALIFORNIA
September, 1930

REVIEWS AND NEW PUBLICATIONS

Introductory Economic Geology. By W. A. TARR (McGraw-Hill Book Company, Inc., New York, 1930). 664 pp., 6 × 9 inches, 249 illus. Price, $5.00.

This book shows the effects of recent influences on the academic profession. One effect is the arrangement of the subject matter, and another is the manner in which it is written. The volume is arranged in order of the materials of most *economic* importance, giving first the metallic and second the non-metallic. This is preceded by a very interesting discussion of the uses of these materials by man through the historic ages and a textbook discussion on the general principles of the formation of mineral deposits. The subject matter is treated from a practical standpoint rather than from that of theory, chronology, or origin. The history of the use of earth materials by man is treated briefly and strikes the keynote of the whole book, that of an interesting story rather than a collection of theories, facts, and observations.

At the end of each chapter is a bibliography which emphasizes the most important books on the subject, from which the author has taken many ideas, pictures, and illustrations. The writer expresses his views on many subjects.

The volume is well written and edited. It will serve as an excellent textbook in elementary economic geology classes and a good reference for the general library.

CLARK MILLISON

TULSA, OKLAHOMA
August 25, 1930

Gerland's Beiträge zur Geophysik; Ergänzungshefte für Angewandte Geophysik. Published by V. Conrad and J. Königsberger.

The increasing interest in the applied geophysical methods have led Professor Königsberger of Freiburg i. Br. and the publishers of the well known *Gerland's Beiträge zur Geophysik* to establish a companion and supplementary journal, which shall be devoted to the field of applied geophysics. The papers on "pure" geophysics will be published in *Gerland's Beiträge zur Geophysik*. The papers on applied geophysics will be collected and published in the *Ergänzungshefte für Angewandte Geophysik*. The language of the papers published may be German, English, French, Italian, or Spanish. The new journal will have four numbers to the volume. The subscription price is 40 marks (about $10.00) per volume.

DONALD C. BARTON

HOUSTON, TEXAS
August 20, 1930

"Salzgletscher in Persien" (Salt Glaciers in Persia). By GEORGE MARTIN LEES. *Mitt. d. Geol. Gesell. in Wien*, Bd. 20 (1927), pp. 29-31.

On account of the extremely dry climate, the salt cores of many Persian salt domes form low, snow-white mountains. Where the salt mountain is of considerable size, the salt begins to flow down the valleys under its own weight, and nunataks, as it were, are left projecting through the salt "glaciers." The phenomenon of the flowage of the salt at the present surface is shown by many of the domes. The base of the salt mountain, Kuh-i-Namak (Salt Mountain) for example, has mushroomed out in all directions over the jagged ends of the steeply dipping Cretaceous limestone which surrounds the salt core, but has left nunataks of the Cretaceous limestone projecting through the salt. The author estimates that with a probable maximum error of more than 50 per cent, the magnitude of the thickness of the load of salt necessary to produce flowage of the salt is 1,100 meters. That load corresponds with a pressure of 220 kilograms per square centimeter and contrasts strongly with the results of Fulda's recent experiments, which showed a pressure of 7,700 kilograms per square centimeter necessary to produce flowage at 25° C. (108,000 pounds per square inch at 77° F.)

Lees' observations contradict also the results of Van Tuyl's recent work, which showed pressures of 29,000 and 27,000 pounds per square inch at the respective temperatures of 20° C. and 30° C. necessary for flowage of the salt. The geology of salt domes other than the Persian domes long has seemed to suggest to the reviewer that flowage of the salt takes place in nature at very much lower temperature and pressure than the results of laboratory experimentation seem to permit.

DONALD C. BARTON

HOUSTON, TEXAS
September 15, 1930

The Mineral Industry of the Far East. By BORIS P. TORGASHEFF. The Chali Company, Ltd., 6, Kiukiang Road, Shanghai, China. 516 pp., 320 statistical tables, 14 maps. Price, post free, £ 2 ($10.00).

In this volume, filled with data concerning mineral geography and statistics, the author has brought together from scattered sources a mass of information on the mineral industry of the Far East, much of which has not heretofore been available in English. Considering the general inadequacy of the materials upon which a volume of this character must be based, the reviewer thinks that the work has been done with much appreciation and thoroughness.

To the specialist in petroleum, however, the volume will be somewhat disappointing for the reason that it adds very little to the information on petroleum already available. Inasmuch as approximately only ten pages are devoted to the subject of petroleum, the various areas are necessarily treated very briefly. A much fuller discussion of the Japanese oil fields would seem to have been feasible and would have been welcome to geologists. The author is inclined to give credence to the belief that the oil possibilities of China have been purposely minimized in other countries and that important discoveries

may have been concealed for commercial reasons. The Sakhalin oil fields, of greatest interest at present, are briefly treated, and the information given is not very recent.

The petroleum resources of the Far East constitute a difficult field for the mineral economist, and the handicap under which the author worked in compiling this chapter on petroleum must be fully recognized. The book is indispensable to those interested in the natural resources of the lands across the Pacific.

W. B. Heroy

New York, New York
September 12, 1930

RECENT PUBLICATIONS

ALASKA

"Geology and Mineral Resources of Northwestern Alaska," by Philip S. Smith and J. B. Mertie, Jr. *U. S. Geol. Survey Bull. 815* (Supt. Documents, Washington, D. C., 1930.) Price, $1.00.

CALIFORNIA

Stratigraphy and Faunal Horizons of the Coastal Ranges of California, by Bruce L. Clark. (1930). 30 pp. plus 50 plates. Paper. Price $3.00. Address, Bacon Hall, University of California, Berkeley, California.

COLOMBIA

"Géologie pétrolifère de la Colombie," by Enrique Hubach. *La Revue Pétrolifère* (Paris, August 16, 1930), pp. 1129-32, 6 photographs.

"Caractères géologiques probables de la Zone pétrolifères de Santander Nord," by Enrique Hubach. *La Revue Pétrolifère* (August 16, 1930), pp. 1140-43, 2 photographs, 1 map.

GENERAL

"Shorter Contributions to General Geology, 1929." (A) "The Occurrence and Origin of Analcite and Meerschaum Beds in the Green River Formation of Utah, Colorado, and Wyoming," by W. H. Bradley; (B) "The Contact of the Fox Hills and Lance Formations," by C. E. Dobbin and J. B. Reeside, Jr.; (C) "The Helderberg Group of Parts of West Virginia and Virginia," by F. M. Swartz; (D) "Petrography of the Pioche District, Lincoln County, Nevada," by J. L. Gillson; (E) "The Varves and Climate of the Green River Epoch," by W. H. Bradley; (F) "Contact Metamorphism of the Rocks in the Pend Oreille District, Idaho," by J. L. Gillson; (G) "Early Pleistocene Glaciation in Idaho," by C. P. Ross; (H) "The Flora of the Frontier Formation," by E. W. Berry; (I) "Borate Minerals from the Kramer District, Mohave Desert, California," by W. T. Schaller. *U. S. Geol. Survey Prof. Paper 158* (Supt. Documents, Washington, D. C.). 173 pp., 27 pls., 45 figs. Price, $0.70.

"Geochemie der Erdöllagerstätten erläutert an den rumänischen Vorkommen," by Karl Krejci. *Abhandlungen zur praktischen Geologie und Berg-*

wirtschaftslehre, Band 20 (Wilhelm Knapp, Halle (Saale), Germany, 1930). 56 pp., 12 illus. Price, 5.50 R. M.

"Types of Oil Field Structures," by W. F. Cloud. *Oil Weekly* (Houston, Texas, August 29, 1930), pp. 55, 56, 60, 62, 8 figs.

Coal Carbonisation, by R. Wigginton. (Charles C. Thomas, Springfield, Illinois, and Baltimore, Maryland; Baillière, Tindall and Cox, 7 and 8 Henrietta Street, Covent Garden, London, 1930). 287 pp., 47 illus. $5\frac{1}{2} \times 8\frac{1}{2}$ inches, cloth. Price, $6.50, postpaid.

"The Recovery of Oil from Sands by the 'Gas Drive,'" by Joseph Chalmers, I. H. Nelson, and D. B. Taliaferro. *U. S. Bur. Mines Rept. of Investigations 3035* (U. S. Bur. Mines, Washington, D. C., 1930). 12 pp.

"Possible Sources of Oil Indicated," by F. C. Grimes. *California Oil World* (Los Angeles, California, August 14, 1930), pp. 11, 18.

"Petroleum in 1928," by G. R. Hopkins and A. B. Coons. *U. S. Bur. Mines* (Supt. Documents, Washington, D. C.). 89 pp., 9 illus. Price, $0.15.

"Physical and Chemical Characteristics of Oil Sands," by W. F. Cloud. *Oil Weekly* (Houston, Texas, September 12, 1930), pp. 40-42, 92.

GEOPHYSICS

"Balanza de Torsion Eötvös," by Pedro C. Sanchez. *Ingenieria* (Mexico City, Mexico, July, 1930), pp. 265, 269, 3 figs.

"Das Magnetitvorkommen vom Sonntagsberge bei St. Veit an der Glan (Kärnten)," by K. A. Redlich. *Zeits. für prak. Geol.* (Halle (Saale), Germany, August, 1930), pp. 121-23, 2 illus.

"Fortschritte der angewandten Geophysik," by J. B. Ostermeier-Althegnenberg. *Intern. Zeits. für Bohrtechnik. Erdölbergbau und Geologie* (Vienna, August 15, 1930), 20 pp., 21 illus.

GERMANY

The Preussischen Geologischen Landesanstalt, Invalidenstrasse 44, Berlin N 4, Germany, announces the following publications.

"Alter und Entstehung des Wald-Erbacher Roteisensteins (Grube Braut im Hunsrück) mit einer Stratigraphischen Untersuchung der Umgebung," by Martha Wolf. *Heft 123* (1930). 105 pp., 5 pls., 1 fig.

"Die Fauna des deutschen Unterkarbons," Part 1. Contains "Die Echinodermen des deutschen Unterkarbons," by W. Erich Schmidt; "Die Gastropoden des deutschen Unterkarbons," by Friedrich Kühne; and "Die Brachiopoden des deutschen Unterkarbons," Part 1, by Werner Paeckelmann. *Heft 122* (1930). 326 pp., 24 pls., 21 figs.

"Zur Kenntnis des Oberdevons am Enkeberg und bei Balve (Sauerland)," by Werner Lange. *Heft 119* (1929). 132 pp., 3 pls., 39 illus.

"Die Ostracoden des Oberdevons," Part 1, by Hans Matern. *Heft 118* (1929). 100 pp., 5 pls., 3 illus.

"Die Kreideablagerungen zwischen Elbe und Jeschken." Part II. "Die nordböhmische Kreide zwischen Elbsandsteingebirge und Jeschken und das Zittauer Sandsteingebirge," by Hermann Andert. *Heft 117* (1929). 227 pp., 13 pls., 5 tables, 13 illus.

KANSAS

"Circular Structural Depressions in Central Kansas," by John L. Rich. *Bull. Geol. Soc. Amer.*, Vol. 41 (New York, New York, June, 1930), pp. 315-20, 2 figs.

The State Geological Survey of Kansas, Lawrence, Kansas, announces the publication of the following maps.

"The Surface Features of Kansas," by Raymond C. Moore. Scale, 20 miles to the inch; map dimensions, 10 × 20 inches; cross section and explanation, 23 × 24 inches. Mailing charges, $0.10.

"Geologic Map of Kansas," by Raymond C. Moore. Scale, 20 miles to the inch; map dimensions, 10 × 20 inches; east-west geologic cross section and explanation, 23½ × 25½ inches. Mailing charges, $0.10.

MICHIGAN

"Characteristics of Geological Structure in Michigan," by R. B. Newcombe. *National Petroleum News* (Cleveland, Ohio, August 20, 1930), pp. 53-56, 1 illus.

OKLAHOMA

"Wanette Producing Sand Not Definitely Correlated," by Floyd Swindell. *Oil Weekly* (Houston, Texas, September 5, 1930), pp. 43-46, 3 illus.

RUSSIA

"Geologie der Erdölfelder von Baku," by R. Schreiter. *Intern. Zeits. für Bohrtechnik, Erdölbergbau und Geologie* (Vienna, September 1, 1930). 5 pp., 2 illus.

TEXAS

"Two Great Producing Horizons in Southwest Texas," by Richard A. Jones. *Oil Weekly* (Houston, Texas, August 22, 1930), pp. 38-41, 49-50, 5 illus.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

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Ivan J. Fenn, E. H. Sellards, Charles Schuchert

Karl Krejci, Canton, China
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W. B. Wilson, W. R. Longmire, Anthony Folger
Willy Hafner, Dallas, Tex.
K. H. Schilling, W. Dow Hamm, F. W. Bartlett
Joe C. Hemphill, Midland, Tex.
C. E. Hyde, Charles D. Vertrees, Paul B. Hunter
Robert Lee Jones, Beeville, Tex.
E. D. Klinger, Philip S. Schoeneck, J. B. Whisenant
Howard M. Kirk, Tampico, Mexico
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Paul S. Oles, Wichita Falls, Tex.
W. F. Brainerd, A. M. Lloyd, C. W. Clark
Robert D. Patterson, Bakersfield, Calif.
Art R. May, Roy R. Morse, E. F. Davis
William W. Porter, II, Los Angeles, Calif.
James W. Hunter, Oliver B. Knight, Frederick P. Vickery
Byron Rife, San Antonio, Tex.
Wesley G. Gish, H. Smith Clark, E. A. Keeler
Albert W. Sands, Santa Paula, Calif.
C. R. McCollom, Donald D. Hughes, Irvine E. Stewart
Francis S. Williams, McPherson, Kan.
Noel H. Stearn, J. M. McGirl, T. C. Hiestand

SOCIETY OF PETROLEUM GEOPHYSICISTS

The Society of Petroleum Geophysicists was organized formally at a meeting of geophysicists at Houston early in the summer (1930). The object of the society is to bring together geophysicists who are engaged in oil work and to advance the science of the application of physics in oil geology. The requirements for membership follow.

A. *Members.*—1. Any geophysicist of recognized standing shall be eligible to membership, whether or not he is engaged in petroleum geophysics or in geophysical prospecting.

2. Any physicist, mathematician, geologist, or engineer of recognized standing who is investigating a geophysical problem or problems shall be eligible to membership.

3. Any geologist of recognized standing who is not a geophysicist of recognized standing but who is acting as chief, assistant chief, or division chief in charge of geophysical surveying of recognized standing shall be eligible to membership.

B. *Associates.*—1. Any geophysicist, geologist, engineer, mathematician, or physicist who is a graduate of an institution of recognized scientific standing who is engaged in geophysics but who is not eligible to membership.

2. Any person who is not a graduate of an institution of recognized scientific standing and who is not eligible to membership but who has shown ability in a routine phase of geophysical work and who is in a position of responsibility in geophysical surveying.

The following officers were elected: president, Donald C. Barton; vice-president, E. E. Rosaire; secretary-treasurer, John Weinzierl.

Application blanks can be obtained from the secretary at 608 Petroleum Building, Houston, Texas. If an applicant is unable to obtain the requisite number of active members as sponsors, the executive committee will accept temporarily, as sponsors, geophysicists or geologists of recognized standing who are known to the executive committee.

INTERNATIONAL GEOLOGICAL CONGRESS—SIXTEENTH SESSION UNITED STATES OF AMERICA — 1932

First Circular

Washington, D. C., September, 1930.

The International Geological Congress, at its fifteenth session, held in Pretoria, South Africa, in 1929, accepted the invitation of the geologists of the United States of America to hold the next meeting of the Congress in the United States.

Upon notification of this acceptance, representatives of the principal geological groups in the United States selected a Committee on Organization in accordance with the rules adopted by the general assembly of the Thirteenth Congress at Brussels in 1922.

Committee on Organization

The officers and members of the Committee on Organization so far chosen are as follows.

OFFICERS

Honorary President . . . . Herbert Hoover, President of the United States
Chairman of the Committee . . . . Waldemar Lindgren
Massachusetts Institute of Technology
General Treasurer . . . . Edward B. Mathews, Johns Hopkins University
General Secretary . . . . W. C. Mendenhall, U. S. Geological Survey
Assistant Secretaries . . . . H. G. Ferguson, U. S. Geological Survey
M. I. Goldman, U. S. Geological Survey

MEMBERS

L. K. Armstrong, 722 Peyton Building, Spokane, Washington
H. Foster Bain, American Institute of Mining and Metallurgical Engineers, 29 West 39th Street, New York City
A. M. Bateman, Yale University, New Haven, Connecticut
C. P. Berkey, Columbia University, New York City
Eliot Blackwelder, Stanford University, California
Isaiah Bowman, American Geographical Society, Broadway at 156th Street, New York City
H. A. Buehler, State Geological Survey, Rolla, Missouri
R. A. Daly, Harvard University, Cambridge, Massachusetts
A. L. Day, Carnegie Geophysical Laboratory, Washington, D. C.
E. DeGolyer, 65 Broadway, New York City
C. A. Fisher, 711 First National Bank Building, Denver, Colorado
H. G. Ferguson, U. S. Geological Survey, Washington, D. C.
M. I. Goldman, U. S. Geological Survey, Washington, D. C.
W. O. Hotchkiss, College of Mines, Houghton, Michigan
Arthur Keith, National Research Council, Washington, D. C.
H. B. Kummel, State Geological Survey, Trenton, New Jersey
H. Landes, University of Washington, Seattle, Washington
A. C. Lawson, University of California, Berkeley, California
C. K. Leith, University of Wisconsin, Madison, Wisconsin
W. Lindgren, Massachusetts Institute of Technology, Cambridge, Massachusetts
E. B. Mathews, Johns Hopkins University, Baltimore, Maryland
W. C. Mendenhall, U. S. Geological Survey, Washington, D. C.
R. A. F. Penrose, Jr., Bullitt Building, Philadelphia, Pennsylvania
Sidney Powers, Amerada Petroleum Corporation, Tulsa, Oklahoma
W. E. Pratt, Humble Oil and Refining Company, Houston, Texas
George Otis Smith, U. S. Geological Survey, Washington, D. C.
Scott Turner, U. S. Bureau of Mines, Washington, D. C.
W. E. Wrather, 4300 Overhill Drive, Dallas, Texas
David White, U. S. Geological Survey, Washington, D. C.

The Committee on Organization has appointed the following officers and members as an Executive Committee.

Executive Committee

The Chairman
The General Treasurer
The General Secretary
H. Foster Bain, American Institute of Mining and Metallurgical Engineers, New York City
C. P. Berkey, Columbia University, New York City
E. DeGolyer, Amerada Petroleum Corporation, New York City
David White, U. S. Geological Survey, Washington, D. C.

Date of the Congress

The general sessions of the Congress will be held early in June, 1932, in Washington, D. C. The precise date will be announced in a later circular. The date chosen promises the best average weather, favorable rates and time for ocean travel, and the customary summer reductions in fares offered by railroads.

The general sessions will be preceded, late in May, and followed, in June and early in July, by a series of excursions designed to afford the members and attendants opportunity to see features of special geological interest in the United States. Short excursions to interesting places in and near Washington will probably be made during the sessions.

Membership

The conditions of membership in the Congress are outlined in paragraph 8 of the Rules adopted by the Thirteenth Congress, held at Brussels in 1922, here quoted.

> No professional title is required to support a request to register. Nevertheless, the excursions organized before and after the session will be more especially reserved for the members of the Congress who are geologists, geographers, and mining engineers and for other persons who devote themselves to the study or practice of some branch of geology.

Topics Proposed for Consideration

Following the admirable practice of recent congresses, each of which has prepared a special volume on the world reserves of some mineral resource that is particularly well represented in the country in which the Congress is held, the Organization Committee of the Sixteenth Congress is planning the preparation and publication of a monograph on the petroleum resources of the world. It is expected that selected papers on the geology of petroleum will have conspicuous places on the program of the sessions.

Other topics of current interest to geologists are also proposed for consideration by those who plan to attend the Congress. These topics are here listed. Offers of papers or comments on these topics or suggestions as to other desirable topics are invited and should be submitted to the General Secretary as soon as possible.

1. Estimates of geologic time by any method
2. Batholiths and related intrusives
3. Origin of lead and zinc deposits of the general type of those of the Mississippi Valley and Silesia
4. Zonal relations of metalliferous deposits
5. Evidences of cycles in sedimentation, including varves
6. Major divisions of the Paleozoic system
7. Boundaries of the Tertiary system and its major divisions
8. Adaptation of extinct animals and plants to their environment as indicated by fossils
9. Physiographic processes in arid regions and their resulting forms and products
10. Fossil man

Excursions

The excursions to be offered have not been finally determined. Those here listed are subject to change or withdrawal, and additional excursions may be offered or may be substituted for any of those listed.

EXCURSIONS BEFORE THE SESSIONS

The excursions to be made before the sessions, with the exception of one across the continent for members who may reach the United States by way of the Pacific, will be confined to the eastern part of the United States and, so far as possible, will be arranged for groups of specialists in the various branches of geology. It is expected that most of our visitors will arrive at New York. Arrangements will be made by the local geologists to act as a reception committee and to offer several one-day field excursions and visits to the local institutions. It is expected that visitors may wish to take advantage of these opportunities in advance of the regular listed excursions of a more extended character.

The excursions in the northeastern states will start from New York City. The excursions in the southern states will start from Washington. All these excursions will run concurrently and will occupy about 10 days, the exact period covered depending on final decisions as to details of the itineraries. The excursions listed are under consideration.

1. Adirondack Mountains and Connecticut Valley. By motor-bus from New York. Of general interest, but particularly interesting to petrologists, structural geologists, and geomorphologists.

2. Mining districts of the Eastern States and Mississippi Valley. By rail from Washington. Designed primarily for economic geologists. The following places will probably be visited: Pittsburgh, Pennsylvania (coal, metallurgy); Rosiclare, Illinois (fluorspar); southeastern Missouri (iron, lead); Joplin, Missouri (lead and zinc); Little Rock, Arkansas (bauxite); Magnet Cove, Arkansas (petrology and mineralogy); Birmingham, Alabama (iron, coal); Cartersville, Georgia (manganese); Ducktown, Tennessee (copper); and Knoxville, Tennessee (zinc).

3. The Appalachian Mountains, between Maryland and Tennessee. By motor-bus from Washington. Designed primarily for structural geologists and Paleozoic stratigraphers. The excursion will pass through the coal and oil regions of West Virginia and thence across the Appalachians to Bristol and Knoxville, Tennessee, returning to Washington along the Shenandoah Valley.

4. Western New York and Pennsylvania. By motor-bus from New York. Designed primarily for Paleozoic stratigraphers, but of interest also to glaciologists, geomorphologists, and structural geologists. The excursion will follow the Hudson Valley to Albany, will thence go westward across New York State to Niagara Falls, crossing the Paleozoic section; thence southward to Tyrone, Pennsylvania, and thence eastward through the region of folded beds in the northern Appalachians to Philadelphia, returning to New York across the New Jersey Highlands.

5. Atlantic Coastal Plain. Designed primarily for Tertiary and Cretaceous stratigraphers and paleontologists. Trip probably in part by boat through the coastal waters of Maryland and Virginia and in part by motor-bus. Itinerary in detail not yet determined.

6. Glacial geology of the North-Central States. Itinerary not yet determined.

7. Transcontinental trip for those landing at San Francisco. San Francisco to New York by train, with stops at Bakersfield, California (oil fields); Grand Canyon, Arizona; Santa Fe and Taos, New Mexico (Indian villages); and St. Louis, Missouri (stratigraphy, iron and lead deposits, glacial geology).

In addition to these excursions, several short excursions in the vicinity of New York may be offered for the benefit of those arriving a few days early and also for those who do not care to take the longer excursions to be made before the meeting of the Congress. More definite announcement concerning these will be made in a later circular.

EXCURSIONS DURING THE SESSIONS

It is planned to devote 3 or 4 days during the sessions to short excursions to places of interest in the District of Columbia and in near-by parts of Pennsylvania, Maryland, and Virginia. These trips will be so planned as not to interfere with attendance at the sessions.

EXCURSIONS AFTER THE SESSIONS

Two transcontinental excursions and two shorter excursions, to be made after the sessions of the Congress, are under consideration.

8. First transcontinental excursion. By special train from Washington. On the trip westward, visits will be made to places in New Mexico and southern Arizona, including the Carlsbad Caverns, the copper-mining districts of Santa Rita, New Mexico, and Bisbee, Globe, and Miami, Arizona, and opportunity will be afforded for a study of desert morphology and southwestern stratigraphy. Stops of several days will be made at Los Angeles and San Francisco, from which short excursions will be made for observation of oil fields, the stratigraphy and structure of the Coast Ranges and the Sierra Nevada, including the Mother Lode, Yosemite, and other interesting features. On the return trip visits may be made to the Yellowstone, Zion, and Grand Canyon National parks, and sufficient time may be allowed at Salt Lake City and Denver for short excursions to areas of special geologic interest. The excursion will require about 32 days.

9. Second transcontinental excursion. By rail from Washington. On the trip westward parts of central Arizona and the Grand Canyon will be visited.

Stops will be made at Los Angeles and San Francisco and a visit will be made to the Yosemite National Park. From San Francisco the party will go north to Portland, Oregon, visiting Crater Lake en route. On the east-bound trip stops will be made at Spokane, Washington (Grand Coulee); Coeur d'Alene mining district; Butte, Montana (copper mines); Yellowstone National Park; Badlands of North Dakota; Mesabi iron district, Minnesota; Chicago, and Niagara Falls. This excursion will occupy about 33 days, and the number participating in it will necessarily be limited.

10. Iron and copper districts of the Lake Superior region. Designed primarily for economic geologists, but of interest also to glaciologists and pre-Cambrian geologists. By train from Washington to Negaunee, Michigan (1½ days), thence by motor-bus or automobile through the northern peninsula of Michigan and northeastern Minnesota, returning to Washington by rail. Duration about 13 days. Those who may desire to do so can go from Chicago to Salt Lake City after making this excursion and join the first transcontinental excursion (8).

11. Oklahoma and Texas. Designed primarily for petroleum geologists and stratigraphers. By rail from Washington to Tulsa, Oklahoma (1½ days —oil fields and structural geology); thence by automobile or motor-bus across Oklahoma and Texas (Cretaceous and Tertiary stratigraphy) to Houston, Texas (salt-dome oil fields). Return to Washington by rail. Duration about 10 days. This excursion, if offered, may be transferred to the group preceding the Congress in order that those who take it may not be excluded from participation in one of the transcontinental excursions.

In addition to the foregoing excursions the following have been suggested, but owing to the length of time and the expense they involve, they will be offered only if a sufficient number express a desire to take them. The Alaskan and Hawaiian excursions will require between 3 and 4 weeks each.

12. Motor-bus trip from Denver through the Rocky Mountains and parts of the Plateau and Great Basin provinces.

13. Southeastern Alaska.

14. Hawaiian Islands.

COSTS

It is not yet possible to state definitely the cost of any of the excursions. The expense of traveling in the United States on such trips as here outlined is about $15.00 a day for railroad travel and about $10.00 a day for motor-bus travel, these figures including subsistence. More definite statements as to expenses will be given in a later circular.

PARTICIPATION IN EXCURSIONS

The Organization Committee of the Congress, acting through the Executive Committee, reserves the customary right to select participants in the excursions without regard to priority of application. The work of this committee in planning the excursions will be made easier if those expecting to attend the Congress will fill out and mail the accompanying form. This form is not an application for participation in the excursions and in no way obligates the sender to participate in them; it is only intended to aid the committee in deciding

which of the excursions tentatively outlined will be finally offered. Those who mail the form promptly, however, will receive the next circular, which will contain more detailed information.

General Information

Inquiries or proposals relating to the work of the sessions or to the future activities of the Congress should be addressed to the Organization Committee through the General Secretary.

Those who receive this circular will be rendering appreciated aid by bringing it to the attention of anyone not receiving it who may be interested in the Congress or in its program.

Circulars to be issued later will present additional details and will record progress in the development of plans for the Congress.

The cable and radio address of the Sixteenth Congress is Intergeol, Washington.

All communications should be addressed to the
General Secretary,
Sixteenth International Geological Congress,
Washington, D. C.

On behalf of the Organization Committee,
Waldemar Lindgren, *Chairman*
W. C. Mendenall, *General Secretary*

I hope to attend the Sixteenth International Geological Congress at Washington in June, 1932.

I believe that the topics listed in the circular opposite the numbers that I have underlined below will be most productive of general interest and discussion [underline numbers of preferred topics]: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

I may be able to offer a paper on topic No.......

I am interested in the following excursions.

	First Choice	Second Choice
Excursions before the sessions	....	....
Excursions after the sessions	....	....

Name..

Address...

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Memorial

GEORGE WHITNEY ADAMS

George Whitney Adams was born in Quasqueton, Iowa, January 13, 1872. He died, May 18, 1930, at Brownwood, Texas, survived by his wife, Alice Crittenden; three children, Mrs. Milton A. Line, Kenneth Adams, and George Whitney Adams, Jr.; and one sister, Mrs. J. N. Adams.

Mr. Adams received the degree of Bachelor of Arts from Doane College, Crete, Nebraska. He was affiliated with the Colorado Scientific Society and Colorado Society of Engineers. He was elected to membership in The American Association of Petroleum Geologists in 1922.

Mr. Adams attended Doane College from 1898 to 1901, during which time he majored in geology. From 1903 to 1912 he was engaged in mining and mining engineering for the National Tunnel Mining Company of Colorado. For the next two years he was United States Mineral Surveyor for Colorado. From 1914 to 1916, he was employed in land surveying and drainage in Florida. In 1916 he returned to Colorado and until 1918 was manager and chemist for the American Metals Production Company at Central City. During the war, and until 1920, he was employed in mining and geological consulting work in Denver. He formed a partnership with the writer under the firm name of Adams and Becker, and was well acquainted with mining conditions in the central part of Gilpin County. At the end of this partnership in mining work in Colorado, Mr. Adams began his work as petroleum geologist in Texas and Arkansas, remaining in this work until he died.

Mr. Adams had gained a wide knowledge of the Mid-Continent area and located several fields of real merit. He was a man of the highest Christian character, energetic, truthful, and lovable.

CLYDE M. BECKER

CHICKASHA, OKLAHOMA
August, 1930

AT HOME AND ABROAD

EMPLOYMENT

The Association maintains an employment service at headquarters under the supervision of J. P. D. Hull, business manager.

This service is available to members who desire new positions and to companies and others who desire Association members as employees. All requests and information are handled confidentially and gratuitously.

To make this service of maximum value it is essential that members coöperate fully with Mr. Hull, especially concerning positions available to active and associate members.

B. DELBERT JONES is a consulting geologist, with offices at 419 Sherman Building, Corpus Christi, Texas.

F. O. MARTIN, who has been on the geological staff of the Union Oil Company, at Los Angeles, California, since 1919, and who has engaged chiefly in foreign exploration, has resigned to engage in independent consulting work.

OLIVER B. KNIGHT, division geologist for the Huasteca Petroleum Company, at Tampico, Mexico, is the author of an article on "Economic Comparison of Developments in South Field of Mexico," in the August 20 issue of *National Petroleum News*. This article, which is *A. I. M. M. E. Technical Publication 343*, is to be presented at their Tulsa meeting.

JOHN F. WEINZIERL, consulting geologist, Houston, Texas, has an article "In Defense of Geophysics," in the August 29 issue of *The Oil Weekly*.

W. W. KEELER, chief geologist for the Minnehoma Oil and Gas Company, Tulsa, Oklahoma, has been transferred to Fort Worth, Texas, where he will be chief geologist for the Geo. F. Getty Oil Company and the Geo. F. Getty Petroleum Corporation. All three organizations are subsidiaries of Geo. F. Getty, Inc., of Los Angeles, California.

D. M. WALLACE, of Fort Worth, Texas, who has had charge of the Geo. F. Getty Petroleum Corporation's operations in Texas and of the Geo. F. Getty Oil Company's activities in New Mexico, has resigned to engage in general consulting work.

E. B. HOPKINS, consulting geologist, 25 Broadway, New York City, will spend the winter in San Antonio, Texas.

SHIRLEY L. MASON, of Pittsburgh, Pennsylvania, sailed August 22 for Portuguese West Africa, where he will be employed by the Companhia Petrolia de Angola, Caixa 135, Loanda, Angola.

C. M. BENNETT, of the Vacuum Oil Company, Houston, Texas, spent the summer in California.

R. W. RICHARDS has rejoined the U. S. Geological Survey and has been working in Washington state.

S. F. SHAW, consulting engineer, Carter Oil Company, Tulsa, Oklahoma, has an article on "Increasing the Ultimate Recovery of Oil" in the September issue of *Mining and Metallurgy*. This paper is *A. I. M. M. E. Technical Publication 358*, to be presented at the Tulsa meeting of that organization in October.

H. B. GOODRICH, consulting geologist, 1628 S. Cincinnati Avenue, Tulsa, Oklahoma, spent the summer in Boulder, Colorado.

HENRY N. TOLER, Meridian, Mississippi, and Miss RUTH EINHAUS, of Quincy, Illinois, were married July 5. Mr. Toler is a geologist for the Gulf Refining Company, Shreveport, Louisiana.

J. WHITNEY LEWIS, 1312 Madelaine Place, Fort Worth, Texas, has moved with his family to Havana, where his address is Banco Territorial. Mr. Lewis is making a reconnaissance of the island for Cuban clients.

E. G. WOODRUFF, of the Pioneer Petroleum Corporation, Tulsa, Oklahoma, has an article on "Hugoton Gas Field Has No Dry Holes," in the September 11 issue of the *Oil and Gas Journal*.

HUBERT G. SCHENCK, of Stanford University, devoted the three summer months to stratigraphic investigations in the San Joaquin Valley, California, for the Standard Oil Company.

GLENN M. RUBY, president of the Nordon Corporation, announces a change of address from Vancouver, B. C., to Los Angeles, California, where his office address is the Bartlett Building and his residence address is 849 South Kenniston Avenue.

W. TAPPOLET, who spent his vacation in Switzerland, has returned to Mexico. His address is Geological Department, Apartado 150, Tampico.

DAVID B. REGER, who resigned his position as associate geologist of the West Virginia Geological Survey, effective August 31, 1930, has opened an office as consulting geologist, 217 High Street, Morgantown, West Virginia. Mr. Reger will practice in the geology of the hydrocarbons and non-metallics, with special attention to reports and appraisals on coal, oil, and gas properties, to investigations on water supply and foundations, and to the utilization of earthy materials and mineral waste products.

H. R. VAN GILDER, geologist with The Pure Oil Company in Oklahoma, is taking special post-graduate work in petrology at Yale.

PARKER D. TRASK, research associate in geology, American Petroleum Institute, Frick Chemical Laboratory, Princeton University, Princeton, New

Jersey, has an article on "Mechanical Analyses of Sediments by Centrifuge," in the September-October issue of *Economic Geology*.

W. H. WHITTIER, 240 Hillcrest Road, Berkeley, California, geologist for the last ten years for the Royal Dutch Shell in South America, the Mid-Continent, and California, has resigned from that organization and is taking work for a Ph. D. degree in geology at the University of California.

ROBERT L. KIDD, resident geologist in Kansas for the Empire Oil and Refining Company, has been promoted and will join the Cities Service Gas Company. Mr. Kidd's address is 1513 Johnstone Avenue, Bartlesville, Oklahoma.

JOHN M. LOVEJOY, 39 Broadway, New York, has been elected president of the Mexican Seaboard Oil Company.

GEORGE I. ADAMS, of the department of geology, University of Alabama, University, Alabama, has an article in the September-October issue of *Economic Geology* on "Origin of the White Clays of Tuscaloosa Age (Upper Cretaceous) in Alabama, Georgia and South Carolina."

J. S. SMISER, 23 William Street, Princeton, New Jersey, has been awarded a 1930 fellowship in the Division of Geology and Geography, at Princeton University, according to an announcement by DAVID WHITE, of the National Research Council.

HENRY SCHWEER has resigned from the Shell Petroleum Corporation to take additional geological work in the University of Oklahoma. His address is 326 East Apache Street, Norman, Oklahoma.

GEORGE W. PIRTLE, formerly of Hudnall and Pirtle, consulting geologists, has accepted a position as district geologist in Michigan for the Gibson, Johnson and Borden interests at Muskegon, Michigan.

PROFESSIONAL DIRECTORY

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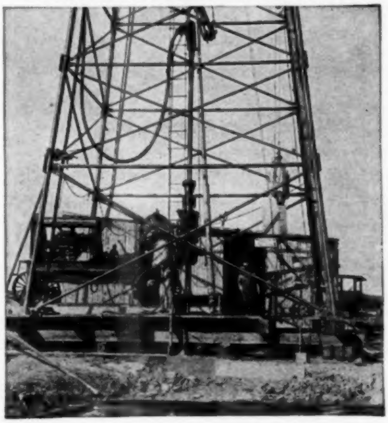

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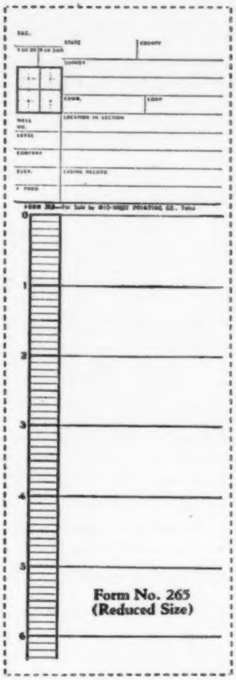

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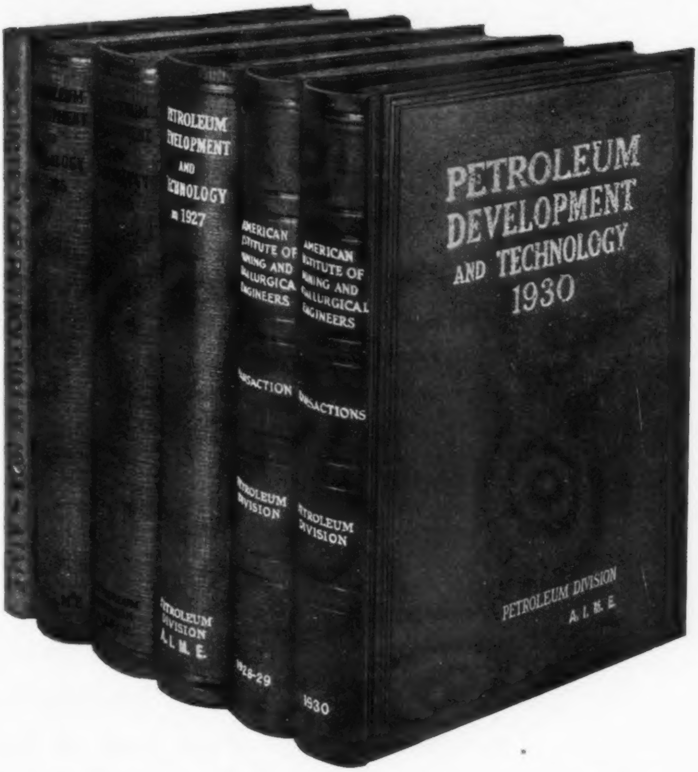

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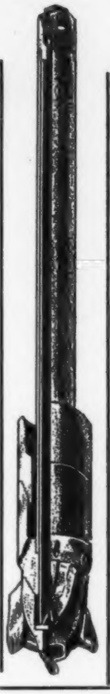

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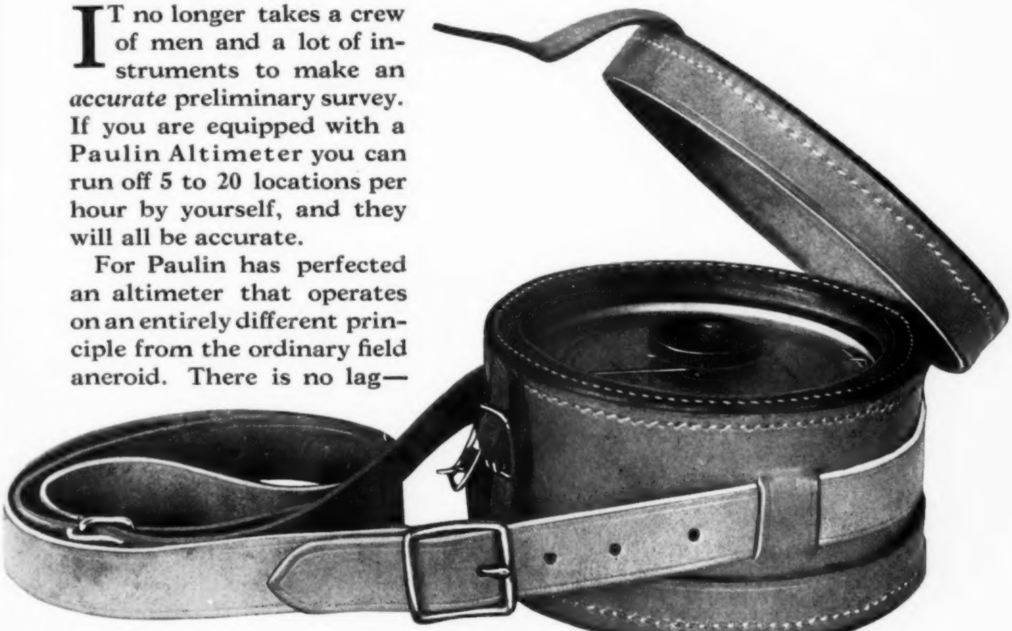

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